THE JOURNAL

OF THE

ROYAL AERONAUTICAL SOCIETY

(FOUNDED 1897 in succession to the ANNUAL REPORTS)

Edited for the Council by J. LAURENCE PRITCHARD, Honorary Fellow

No. 150 JUNE 1923 VOL. XXVII

NOTICES

Election of Members

The following members were elected at a Council Meeting held on May 15th :—

Student.—R. E. Bishop.

Associate Member.—C. F. Woodman.

The Pilcher Memorial Prize.

The Pilcher Memorial Prize for papers read at Students' Meetings during the Session 1922-1923 has been awarded by the Council to A. P. Rowe for his paper on "Aerial Navigation," read at the meeting of December 14th, 1922. This paper will be published in a forthcoming issue of the Journal.

Associate Fellowship Examination

The second examination for Associate Fellowship will take place in the Library on Monday, September 24th (Part I.) and Tuesday, September 25th (Part II.). Intending candidates should forward entry forms (accompanied by the prescribed fee) on or before Monday, August 27th, stating the subjects in which they desire to be examined.

Zaharoff Professor

All members will join in congratulating Professor Bairstow, their Chairman, on his appointment as Zaharoff Professor of Aviation in London University, which has recently been announced.

Library

The following books have been received and placed in the Library :—"A Treatise on Hydromechanics. Part II., Hydrodynamics," 2nd Edition, A. S. Ramsey; "The Evolution of Climate," C. E. P. Brooks; "A Text-Book on Wireless Telegraphy," R. Stanley; "Generalised Linear Perspective," J. W. Gordon; "A Dictionary of Applied Physics. Vol. III., Meteorology," Edited by Sir Richard Glazebrook; "Planes and Personalities," A. C. Reid; "Résumé des Principaux Travaux executés pendant la Guerre au Laboratorie Aérodynamique Eiffel, 1915-18," G. Eiffel; "Notes on the Life of Frederick Marriott," G. R. S. Kirkpatrick; "In Full Flight," E. Vine Hall; "Aerodynamik," Fuchs and Hopf; "Use of Aircraft in Warfare," R. B. Davies; "Optical Methods," Goldsmith, S. Judd Lewis, F. Twynam; "Face of the Earth as Seen from the Air," W. T. Lee; "Météorologie Pratique. Etudes Elementaires," A. Baldit; "British Standard Glossary of Aeronautical Terms," British Engineering Standards Association; "America's Munitions," B. Crowell.

W. LOCKWOOD MARSH, *Secretary.*

PROCEEDINGS

NINTH MEETING, 58TH SESSION

A meeting of the Society was held in the rooms of the Royal Society of Arts, Adelphi, London, on Thursday, February 15th, 1923, Professor L. Bairstow presiding.

The CHAIRMAN, referring to the paper to be read, namely, on "The Practical Aspect of Seaplanes," by Wing Commander T. R. Cave-Browne-Cave, C.B.E., said that this was the third of the series of lectures on seaplanes, a series which came into being mainly at the instigation of Wing Commander Cave-Browne-Cave. The lecturer was a member of the Council of the Society, and had thought that it would be advisable to have a connected series of papers of this description; it could be said that the policy adopted had been successful and would be rounded off by that evening's lecture. The author, in the beginning of the paper, explained what his position was, and that the paper represented other views in addition to his own, so that he (the Chairman) did not propose to enter into that subject, but he asked those present to note, when the paper was read, how the whole cause of seaplane development cried out loudly for further experiment. The conclusions in the paper were more definite than those they usually associated with pilots' opinions on the flying of aircraft, but that they were generally sound he himself had some reason to know. On the other hand, it was quite clear from the paper that the author had not been able to put into numerical form many things which he knew were true in a general way. He then called upon the author to read his paper.

Wing Commander CAVE-BROWNE-CAVE, dealing with the Chairman's remarks that he was putting forward views other than his own, said he believed that was not quite what the Chairman had intended to say, because he (Wing Commander Cave-Browne-Cave) definitely agreed with everything put forward in the paper, and the views expressed had pretty well the complete concurrence of the pilots with whom he had discussed them.

THE PRACTICAL ASPECT OF SEAPLANES

BY WING COMMANDER T. R. CAVE-BROWNE-CAVE, C.B.E., A.M.I.MECH.E., A.M.I.N.A., FELLOW.

INTRODUCTION

Many will wonder why the Council called upon one, other than a practical seaplane pilot of wide experience, to read a paper on this subject. That I cannot answer. The reason for which I agreed to write the paper was partly failure to get any one of the many having better qualifications to do the work, and partly because, having the pleasure of commanding the R.A.F. Establishment at which the marine experimental work is done, I do come into touch with the most expert pilots and designers, and have the opportunity of seeing certain points of view and experiences which may be of interest to members of the Society.

A most valuable cruise was carried out at the end of last summer by a squadron of four large flying boats under the command of Squadron Leader R. B. Maycock, acting as an R.A.F. unit in company with a mother ship. There was a destroyer and the seaplane floating dock in attendance. While it is undesirable to discuss in detail the comparison between the various types of machine

used, and the operations carried out, permission has been given to refer to many of the practical experiences met and to some of the deductions drawn.

The opinions expressed in this Paper have the general concurrence of the pilots of that squadron, and those at Grain, and carry weight for that reason.

The Paper deals with the practical aspects as seen from the Service rather than the commercial point of view, and it will be of great interest to see how experience in the use of seaplanes for commercial purposes modifies the conclusions reached.

The term seaplane includes the boat seaplane and the float seaplane, also those amphibians which are designed to be satisfactory seaplanes and not merely aeroplanes capable of using the water in emergency.

I have to express my indebtedness to the Air Council for permission to read this Paper, it being understood, of course, that nothing contained herein must be regarded *ipso facto* as the officially accepted view.

Flying

The behaviour of seaplanes in the air differs widely from that of aeroplanes. The difference is most marked in flying boats, but exists in all machines that carry a hull or floats.

In the more extreme case of the flying boat, the differences are somewhat startling.

The C.G. is unusually low by reason of the hull or floats, and the thrust line is high, so that the airscrews may be clear of spray. This involves a large change of trim on leaving the water, and a still larger change of trim between engine off and engine on. It is, therefore, usually necessary to adopt a depressing tail placed well in the slipstream, although this is most uneconomical in lift.

A long bow to the hull extending well forward is necessary to avoid diving if alighting steeply. The presence of this area forward renders desirable a long tail with large surfaces. This is usually impossible, and stability and control are therefore bad.

To avoid damage when on the water, it is usual to fit no ailerons on the bottom plane. Control in this respect is therefore bad also. Tail surfaces are necessarily at a considerable distance above the axis of the hull which carries them, and thereby lack rigidity due to the torsion of the hull.

Much of the trouble would be reduced if a good dihedral angle could be adopted, but the consequent raising of the wing tips would allow a very large angle to roll on the water, unless deep wing tip floats were employed.

The fins on the top plane give the same effect as dihedral.

These restrictions result in such alarming differences as the following :—

The nose tends to rise in a sideslip.

It is usually necessary to reverse a control in order to check a swing that has once been started.

To compensate for switching off the engine, it is usually necessary to force the control almost to its extreme forward limit.

Under these circumstances, only the most mild manœuvres can be carried out with safety, and the operations of taking off and alighting, which require certain and accurate fore and aft control, present, under some conditions of sea, difficulties considerably greater than in the aeroplane of corresponding size.

The two pilots of a 700 h.p. flying boat sit abreast, and in bumpy weather are often working right up to the limit of their physical strength. If ever there was a case for the servo motor control it is in the large flying boat. The

ability of the two pilots to work so well together caused me to suggest that controls might be made independent, and worked by separate individuals on the orders of the captain, as is done in a large airship where the energy required in the controls is large. This has never been tried as far as I know.

In steady weather, however, all well-designed flying boats will fly as comfortably " hands off " as will the best aeroplane in the same pleasant conditions.

On the Water

An interesting record of the recent development squadron is that the number of hours actual taxiing on the water was only some 20 per cent. less than the total flying time.

An experienced pilot has expressed the opinion that there is as much difference in handling a seaplane on the water and an aeroplane on the ground as between an aeroplane in flight and one taxiing.

The difficulties of a forced aeroplane landing in unsuitable country have not as a rule any parallel in a forced landing at sea, although other troubles arise in bad weather. The seaplane has no similar advantage in its normal taking off and alighting. The waters it uses are in no respect private aerodromes reserved for the use of aircraft. They are often dotted with ships at anchor or under way and, what is often worse, with buoys and small boats. In addition there is often a tide which may be in any direction to the wind.

A good view ahead is therefore essential. Manœuvrability of a single-engined seaplane is usually bad because control is dependent upon the action of the slip-stream on the rudder, and in order that this may be sufficient to overcome the disturbing air and water forces, considerable engine speed and consequently forward speed is essential.

A water rudder improves matters, but unless its area is made much larger than is at present usual, it is incapable of overcoming the large forces on the air structure.

A water propeller might be similarly ineffective.

A twin-engined machine handles much better on the water, because the air-screws being set wide out exert considerable turning moment. The principal difficulty is in checking the way of the machine. In order to approach a mooring buoy at safe speed it is necessary to use a drogue, even if engines are throttled to the slowest speed at which they will run. Two drogues may be used, and by their added resistance assist steering considerably if there is no wind.

A flying boat, when in tow of a motor boat, yaws wildly unless drogues are used or the tow is made fast to a span to the wing struts.

Towing is an operation in which much useful experience has been gained. A machine does not tow comfortably from a motor boat when a short tow has to be used and accurate manœuvres are called for. She yaws widely unless drogues are used or unless there is a fair wind in a suitable direction.

The use of a tow only a few feet long has recently proved effective.

Towing in the open sea is, however, much easier than anticipated. Greater speeds can be used, and if the speed, length of tow, and use of drogues are adjusted according to circumstances, a flying boat can be towed at considerable speed even in fairly bad weather.

An interesting recent development has been the towing of one flying boat by another. This proved quite easy, as the much greater available range of speed allowed the towing to be adjusted easily to the conditions of wind and sea.

A difficulty that is not always recognised is that in a congested harbour a seaplane pilot can never stop and think. He drifts so rapidly that he must

always be effectively under way unless he is tied up to a buoy or in tow. Small adjustments which are easily made on an aerodrome are therefore attended with greater difficulty.

Seaworthiness,

as applied to aircraft, covers a wide range of circumstances. The ability to get off the water depends on characteristics different from those which control ability to alight and to live safely on the surface.

The fundamental difficulty is the destructive effect of water on parts of the structure designed for air loading. Water is some 900 times the density of air, and even a spray which contains only 1 per cent. of water causes nearly nine times the loading due to air at the same relative velocity. The destructive effect of spray on propellers is therefore obvious.

The best method of mooring, anchoring or towing is by the arrangement of lines shown in the figure. The mooring shackle by which the boat is secured for any of these purposes is carried by a pair of wires made fast to the foot of an inter-plane strut on each side of the machine (in a twin-engine machine the engine struts are usually selected) and by a central wire having at its after end a lignum vitæ thimble running on a bridle attached to the bow point and to a point on the keel.

Secured in this way, the boat rides head to wind, and the bow is free to rise to the waves.

As indicating the seaworthiness of flying boats when properly moored, it is interesting to note the experiences of the machines of the Development Flight at Scillies. The flying boats were moored in an open anchorage, the mother ship lay under shelter inshore. She had to hoist in all her boats except two. The flying boats all reported next morning ready for a rough weather towing trial, which it was, however, decided to abandon.

The resistance offered by the air structure is very considerable, and a mooring of surprising strength is necessary. The lift of the planes becomes sufficient (at some 50 to 60 knots) to take the boat into the air. This has not infrequently occurred. The most striking case of which I have heard, but of which I have not yet managed to find an official report, was told to me by a reliable authority. In this case, which occurred on the Greek Coast, a flying boat was moored to a sinker of considerable though insufficient weight. The wind increased until the boat broke the sinker out of the sea bottom, rose into the air and glided ashore, knocking a hut over with the sinker before landing.

A perfectly authentic case occurred at Scapa Flow, where a three-engined Porte boat flew itself ashore with a set of four sinkers.

To reduce this tendency to fly at their moorings, a device was employed at Scillies during the war, and consisted of 9in. boards secured edge up behind the front struts of the lower plane, thereby destroying its lift.

With some of the flying boats which had low clearance under the wing, it was, for safety after a forced landing in a bad sea, desirable to strip the fabric from the bottom plane. This prevented the water exerting on the wing forces sufficient to break the structure and cause the machine to overturn.

The clearance under the wing of P.5 is only 5ft. 2in., and the free board at the after hatch is 1ft. 7in., but this was found on the last cruise to be ample.

Damage to a wing tip float, although apparently a trifling matter, may result in the complete overturn of the machine unless immediate steps are taken by sending men out to the other wing tip to keep the damaged float clear of the water

It is usually found that alighting in a big sea is worse than remaining on

the water, unless damage has been done on landing. The machine is kept head to wind by the use of a drogue attached to the mooring bridle already described.

Difficulty is sometimes experienced in determining the height above the surface when alighting. This is worst when there is a glassy surface on the water and a low sun to windward, as the glare then is at least twice as bad as over an aerodrome in similar conditions.

A glassy surface with a white mist and no horizon is almost equally bad, and remarkable " virtual landings " 20ft. above, or below, the surface are seen.

Automatic landing with the aid of a hanging stick so connected to the control that it flattens the machine out at the right height above the water, functions very well and renders a forced landing in fog or darkness much safer than over land, unless the water be very rough or is that of a crowded harbour, when ships and buoys may be met.

The limiting factor is generally the ability to get off with a reasonable load.

The margin is often very small and even the slightest temporary increase in power may make all the difference between failure and success.

Except in the open where a big sea may be running, it is usually found that any wind, up to say 40 knots, assists the process of getting off. The most difficult conditions are a long swell and no wind. Under these conditions a boat has run two miles before getting off.

Success depends on an adequate horse-power for the weight carried, and on the sufficiency of longitudinal control to allow the pilot to maintain the right attitude to insure that the boat attains flying speed before she is lifted off the water and sufficient control to avoid stalling immediately she takes off.

A 10cwt. stockless anchor with nine fathoms of 7/16th chain cable holds a spherical iron buoy of some 470lbs. buoyancy. The buoy carries a large wire eye at the top, and this can be easily hooked by the machine. A two-fathom length of 2½in. wire is attached to the chain close under the buoy, and has a large eye spliced in its outer end. This is tied to the top eye when not in use, and being made fast to the boat's mooring shackle, allows her to ride clear of the buoy and free from damage.

The provision of anchor and mooring gear sufficiently light to be carried in the boat presents considerable difficulty. There is room for much experiment on the lightest form of anchor capable of a given holding capacity.

Seaplane Trolleys

The usual method of moving a seaplane on land is to rest it on a specially shaped trolley. With float seaplanes there is comparatively little difficulty, but the process of bringing the hull of a flying boat into its correct position on the trolley is attended with the risk of serious damage to the bottom. The positioning has to be done by men in waders round the trolley, assisted by men on the side gangways of the slipway who steady the machine with wing tip lines.

In the case of an 18-ton machine, such as N.4, which, with her trolley, draws nearly 5ft. of water, the process becomes impossible (except under ideal conditions).

The movement of the hull over the trolley, which is usually under water, often causes damage to the bottom, which is very difficult to make good.

The damage would be largely avoided with a trolley that supported the boat under the docking chocks now provided at the wing roots for dry docking (described later). These chocks are always above water, and it is possible to see

that the position is correct, or to use guide lines to draw the trolley into correct contact with the chock.

In order to overcome the difficulty of using a trolley on the slipway, a buoyant trolley was made with a view to placing it in position while both machine and trolley were afloat.

The water resistance of the trolley with its buoyancy chamber was so great that it was impossible to place it under the machine unless there was no tide stream, and the scheme was therefore abandoned.

Seaplane Dock

Quite the most important recent development in seaplane work has been the floating dock designed by the Admiralty to Air Ministry requirements and made at Sheerness Dockyard. The dock is like an ordinary floating dock, but has a forecastle structure which accommodates a crew and provides machinery and workshop spaces.

The dock is submerged, the machine floated into position above pedestals which are adjusted to lift the machine under the special pads fitted to the wing roots.

The operation can be carried out in any wind, and except with a heavy swell, presents no real difficulty.

On the second occasion of docking a machine at Grain, the boat was lifted clear of the water 16 minutes after the first line was thrown to the machine as she taxied up to the dock mouth.

This method of support, besides minimising risk of damage to the bottom, leaves the bottom exposed for repairs.

The experience of the Development Squadron shows that such a dock is necessary for repairs to the boats' hulls. Certain of these repairs can be temporarily done if a protected sandy beach is available, but for a squadron of flying boats, operating away from a permanent base, a dock such as this is absolutely essential if very rapid loss of boats, through inability to make good damage, is to be avoided.

The dock enables engines to be changed in 48 hours, but without it the vital process of changing engines would be virtually impossible, except at the permanent base.

In fitting out a mother ship for a squadron of flying boats, or in providing an advanced base, say, for commercial operations, it appears necessary that some means of lifting the boat's bottom clear of the water for repairs should be provided until some form of construction altogether more reliable than the present bottom has been evolved.

Points of Design

The improvement which is perhaps most desirable is in the effectiveness of air control.

The shortness of the tail and the lack of rigidity with which it is supported are consequences of carrying the tail on an extension of the hull. Increase of length would therefore involve considerable weight, and an even greater torsional movement.

The solution appears to be in carrying the tail on a fuselage or on two fuselages arranged immediately behind, and co-axial with the airscrews. A fuselage behind an airscrew detracts practically nothing from its efficiency. The tail may then be long and supported symmetrically, so that far less supporting structure and consequent resistance is involved.

With such an arrangement the hull would be cut off at the aft step, and the upper surface swept down to this line.

A tail in this position would be very well protected from water damage, and would have many incidental advantages when the boat was moored.

Bulkheads are desirable to limit the surging of water inside the hull when getting off or in flight, but also as a protection against sinking if the hull is damaged. The construction of a flexible bulkhead in a flexible hull is understood to present some difficulty. If it is agreed that the bulkhead need only be carried to a small distance above normal water level, it can conveniently be stepped over by the crew passing along the hull, and construction would be comparatively simple. Such a bulkhead could certainly be made sufficiently flexible to avoid "freezing" the flexible hull any more than is done by the step board.

Storage of petrol in tanks in the hull in close admixture with W/T and other electrical gear calls for careful consideration. The remarkable properties of streamline petrol tanks fitted under the top wing have been demonstrated. Even if petrol leaking from such tanks is ignited it burns harmlessly in a feather of flame astern of the tank. The rush of air is such that it is almost impossible to ignite petrol issuing in this way.

Storage of the full weight of petrol on the wings involves slightly increased strength of structure and slightly higher wing tip loads, but these are in most opinions fully justified by safety from fire, by gravity feed and the improved accommodation in the hull. The raising of the C.G. is definitely beneficial and the increase of moment of inertia about the longitudinal axis is very small unless the tanks are set wide out.

The central engine room inside the hull, with gear drives to the propeller, has most important advantages. The care, adjustment and control of the engines is greatly improved. Risk of fire is, of course, again introduced, and at present the difficulties of torsional resonance in the shafting and gearing do not appear to have been overcome.

The difficulty of maintaining an aero engine in proper running order when it is washed down with sea water every time the machine takes off can only be fully realised when experienced at first hand.

The disposition of crew is, as a rule, fairly satisfactory. A good view forward for both pilots is essential. It is impossible for either pilot to see over the other side of the boat, as the seats are abreast. A cockpit in the extreme bow is necessary for anchor work, mooring, etc., but this must be fitted with a watertight hatch. The new hulls now being designed by Messrs. Supermarine are admirable in this respect.

More attention to the protection of the pilot from spray is desirable. The boat must be designed so that the propellers are fairly clear of spray. If this care of the propellers is neglected they break. The pilot, on the other hand, has flying clothing, which is not proof against spray driven by a 50-knot wind.

The increase of seaworthiness in large machines is a point on which considerable doubt exists. The water clearances will increase, but the span and length also increase, so that the difference of level of the sea surface under various parts of the machine may increase as rapidly as the clearance. Those of you who have not experienced a sea which is logged according to recognised scale as "moderate," will probably have seen pictures of destroyers rolling about in such a sea. The design of a large machine which can live in a sea of this size, let alone the question of taking off and alighting, is a point which troubles the imagination considerably.

Great discussion ranges round the relative merits of flexible or rigid hulls, but the two general types differ in so many other important particulars that

comparison on the question of flexibility is impossible. The so-called flexible hull is not very flexible at those sections which are most highly loaded. It is difficult to believe that the external surface deflects under load to such an extent as to render the distribution of pressure more uniform. Any flexibility which may be left in the hull after the effect of the rigid step board and the wing root struts has been considered can therefore only act as a shock absorber between the impulsively loaded bottom and the inertia of the weights of the machine. It has been stated that some experiments in America recorded accelerations of 7g. on the bottom of the hull, but I have been unable to get any particulars of the method of trial or the accuracy of the accelerometer.

As compared with the "F" type the "P" boats have a smaller planing bottom and better fore and aft control, so that they attain their full flying speed before taking off. The smaller area of bottom is in itself conducive to less severe shocks when striking a wave, and the better control renders bad shocks still less probable.

On the development cruise the "P" type showed a marked superiority, except that considerable damage to the rigid step was experienced, due no doubt to the presence of a rigid step on a flexible hull. It is very probable, however, that a rigid hull of the same external form might have done equally well, and had no trouble with the step.

Various accessories, if not peculiar to seaplanes, are at any rate of special importance.

A bilge pump which can deal with dirty water and pass a large quantity with the few inches lift necessary is a requirement that is not easily met. Any form of reciprocating pump is apt to meet serious damage at the ends of the stroke if being worked at full speed under considerable stress of circumstances. Most pumps available have a small diameter and long stroke, and consequent maximum friction loss.

A power-driven bilge pump, or perhaps one which would clear out the bilge water while the seaplane is taxiing, would be of great advantage.

Engine starting in cold and wet weather is always a trouble, and there is a very strong case for the gas starter engine. Machines intended for work in winter, and moored out, would benefit from a well-lagged water tank into which the water could be drained and then pumped back when required. A small auxiliary engine for pumping, engine starting, warming water, and perhaps cooking food by the exhaust, would, in my opinion, be one of the most valuable uses for a little of the available lift.

Waterproof engine covers and a rigid cover to the front cockpit are, of course, absolutely essential.

The troubles experienced by the Development Squadron in maintaining the material of their machines in safe and efficient condition were in some respects abnormal, because of the age and initially poor condition of the machines. Their experiences are, however, of exceptional value.

The amount of water absorbed by the hull and wings was difficult to determine accurately, but it was certainly not less than 400-600lbs. on machines carrying only 2,500lbs. of fuel.

The amount of water which is taken up by the hull is, no doubt, only a portion of the total absorption referred to, but avoidance of this added weight becomes an important advantage of the metal hull. For large machines which will pass the majority of their time between flights moored out, the advantages of the metal hull are so important as to justify some increase of weight over the wooden alternative. There is, however, considerable doubt whether in any but small sizes the metal hull would actually be any heavier than the wood type.

Moisture had a further effect in making the planes zoggy, and eventually in destroying some of the 3-ply used.

Corrosion of steel and aluminium parts was very bad.

Much work was required in making good small local damage and cracking of the hulls, a most difficult process, generally impossible unless the boat can be dry docked.

All these troubles, though serious, are not nearly as likely to prove fatal as those resulting from trouble with trolleys on a slipway in bad weather.

We are therefore led to the conclusion that flying boats must, if possible, be made weatherproof, so that they can remain moored out and derive all the consequent advantages of safety and immediate readiness for use.

The large seaplane has certain inherent advantages which have been most clearly demonstrated by Mr. Fairey in his recent paper before the Air Conference. His conclusions are so essentially part of the practical aspect that they should be referred to in this paper.

The difficulties which a large aeroplane encounters in the process of landing become very serious with increase of size. Not only is the necessary size of aerodrome very large, but the actual strength of ground surface which is needed to carry such a large weight is difficult to find.

Even if it were possible to provide an aerodrome capable of meeting these requirements, the consequences of a forced landing where such conditions are not available are serious. The seaplane, as it increases in size, encounters no such increasing difficulties in landing, the indication being that the difficulties connected with rough water will decrease in the larger machines.

In the great majority of country over which aircraft will work, particularly on long distance routes, it will be far more easy to select courses which have a reasonable number of safe landings for seaplanes on rivers, lakes, or the sea, than for emergency aerodromes which meet the more exacting requirements of the aeroplane.*

Conclusion

The practical aspect of the seaplane is one which requires most careful study, because it is in that that we realise the vital requirements of handiness on the water. These not only control and limit the actual use of the machines, but are so hard for a designer to realise unless he is also a seaman of intelligent experience.

The prospects for a carefully developed seaplane are, however, so promising that its study is certainly one of the most interesting branches of aeronautical engineering.

Discussion

General Bagnall-Wild (Director of Research, Air Ministry), opening the discussion, said that it was the first time they had had the seamanship side of aircraft put before them. It must be realised what seamanship meant. In the first place, officers and men must be trained for seagoing duties and learn the language of the sea.

As regards methods of launching seaplanes he was of opinion that the use of the trolley was elementary and was not desirable in that with a big seaplane there is a considerable risk of damage to the hull. In addition, in the future it appeared that all the smaller seaplanes must be amphibians. In front of the sheds there should be a " hard " so that these amphibians could land themselves.

For the bigger machines a dry dock at permanent stations, in his opinion, was essential. It would not be expensive to build a dry dock in tidal waters with suitable protecting aprons. Elsewhere, the floating dock would be quite capable of coping with the biggest machine. Big machines should be capable of being moored out for long periods, even six months at a time.

Mr. JOHN H. NARBETH, C.B., C.B.E., M.V.O., R.C.N.C. (Chairman of the Admiralty and Air Council Joint Technical Committee on Aviation Arrangements in His Majesty's Ships), after thanking the Society for the opportunity given him of hearing the paper, said that, although he was a Naval Architect, he took a very deep interest in all that concerned aviation. Having been at Spithead when Commander Samson had flown from Sheerness, about twelve years ago, he had been fascinated with the flying boat and seaplane subject. The Air Ministry was to be very sincerely congratulated on having allowed Wing Commander Cave-Browne-Cave to make public the experiences of the manœuvres, and the paper seemed to be an exceedingly practical and important one which would give rise to a very great deal of thought and discussion. He hoped that, having made a start with these flying boat manœuvres, they would become annual events. He was present as a member of the public, and was simply voicing his own opinions; it certainly must not be thought that he was expressing Admiralty opinion at all.

Wing Commander Cave-Browne-Cave had said that there were four boats used, and they were of sufficient variety to indicate the choice of type in a very marked way. The Air Ministry had learned one thing quite definitely from these manœuvres, and that was which type of boat they should spend their money on, and no doubt considerable economy of public money would be effected as a result.

The paper clearly demonstrated two things. In the first place, it showed the very remarkable seaworthiness of these flying boats in broken water, and that was a subject upon which he had previously heard some very poor opinions as a result of experiences during the war. Seaplanes which had been at work on the North Sea had disheartened the pilots very much, but during last summer, when these flying boats were on manœuvres, there was a certain amount of wind, and the sea was often rough and never smooth, so that they had on that occasion a very fair opportunity of testing the seaworthiness of the present seaplanes, and a much more favourable report showing that seaworthiness had greatly improved. Secondly, the manœuvres had shown the great value of the floating dock. He had had the honour of being associated with the production of that dock, which dock bore witness to a very important feature in the development of aviation in this country, and that was that, whatever differences of opinion there might be between the Admiralty, the Air Ministry and the War Office as to policy, once a policy was settled and there was something to be done, the technical officers of the various departments combined with the greatest zest. In the production of this seaplane dock the officers and pilots of the Air Force had said exactly what they wanted, naval officers had given advice, and together with the naval architects, who had a very wide experience of floating docks of various types, they all met together, discussed the various types of docks, and agreed to put forward the proposal to build the smallest seaplane dock to take the largest flying boat then in sight. He believed it had been demonstrated that the country's money had been very well spent on that dock. The success of that dock, which was of a unique design, was so great that he was sure it indicated a broader path for the future development of the flying boat services.

The third paragraph of Wing Commander Cave-Browne-Cave's paper deserved to be printed in letters of gold; that was "The opinions expressed in this paper have the general concurrence of the pilots of that squadron, and those at Grain, and carry weight for that reason." We have had a great deal of scientific research, there is an enormous fund of knowledge at the disposal of our designers, and we have reached the point where what was wanted more than

anything else was to make the utmost use of the practical knowledge of the pilots. He was sure pilots could give a vast amount of information, and he was very pleased to know that such pains had been taken to gather from them their practical views, and also that the paper did really express their views. He hoped the Air Ministry would be convinced of the great utility of the flying boat and of the importance of carrying out these manœuvres annually, in order that flying boats of British design and manufacture might continue to be developed with increasing success.

Squadron Leader R. B. MAYCOCK (Grain) disagreed with the author on one or two small details. Although pilots were able to agree on the fundamental aspects of the seaplane, they were still at war with regard to some of the lesser details which, under certain conditions, largely affected the effectiveness of the seaplane. In regard to some of the details, he had never heard of two pilots holding quite the same opinion. In summing up the paper, it seemed to him that perhaps the author had laid more stress on the impracticable side of the seaplane than on the practicable side. In that, of course, he was wise, because the meeting was held for the purpose of discussing the improvement of the seaplane and for general propaganda towards that end, but he believed that the seaplane was not really so severely handicapped in some respects as it might appear, especially when considering it in relation to its heavy sister, the bombing aeroplane. Generally speaking, he believed there was very little aerodynamical difference between them, even in rough weather. There were, however, three important factors about the seaplane which were disadvantageous as compared with the aeroplane. These were, first, the difficulty of taking off in a rough sea and wind, as against an aeroplane taking off from an aerodrome in a similar wind. The second was that the flying boat of the future must be moored out, and the question of corrosion and the weather effects on the machines if wholly exposed was a serious matter, and must always be put against it in comparing it with the machine which was housed, and it was a point which needed considerable attention. Every effort should be made to stop this corrosion. The third difficulty to be got over was the lack of power to enable the machine to overcome the set-back which the author had described when taking off when there was a heavy sea running. A power reserve is necessary to drag the machine on to the step and keep it there until flying speed is attained.

When these difficulties were overcome, and there seemed to be no reason why they should not be, the seaplane would be on absolutely the same level as the aeroplane of the same size, and would be an extraordinarily useful military and commercial machine. Landing in a protected harbour in any weather was no more difficult than landing an ordinary aeroplane on an aerodrome, and he did not think the sea would ever be sufficiently rough to prevent landing in a suitably-protected site. Forced landings on a rough sea were no more hazardous than forced landings by aeroplanes in difficult country or over London; it was a matter of luck and good judgment whether the machine survived, and the risks were fairly equal. Personally, he would sooner land at sea than in London. There was another difficulty in comparing the seaplane with the land machine, and that was that an ordinary aeroplane could land at an aerodrome, and if it had no shed to go into it could be pegged down. The seaplane, under similar conditions, must have a buoy or anchor, and he would like to illustrate by means of slides the strength and weight of the moorings required. The first slide showed a line of moorings, and there were nine machines moored. Three of the machines, during a gale of 102 miles per hour, blew away, carrying their moorings with them. They were single moorings and had one-ton sinkers at the bottom, but the machines had picked the moorings up and had deposited themselves and the moorings on dry land.

They had landed upside-down, resting on the struts, and were broken up.

It must be remembered that in gales of 60 m.p.h. or over the drag on the moorings is approximately equivalent to the lift of the planes and therefore the strength of the moorings must be out of all proportion to the size and weight of the machines as calculated for surface craft. Two further slides were shown depicting the broken machines.

As to hard work on the part of the pilots when controlling large flying boats in the air, pilots had certainly talked of hard work under some conditions, but one heard the same thing from other heavy machine pilots. Once in the air the effort expended in lateral control is normal. The rudder, however, requires more owing to aileron drag and shortness of tail. With regard to the author's remark that his suggestion as to separate controls worked by individuals on the orders of the captain had never been tried, he (Squadron Leader Maycock) thought there can only be one pair of hands in control, because the pilots "felt" the position of the machine through the controls rather than "saw." Probably that was the reason nobody seemed anxious to try the suggestion. Dual control is fitted so that pilots can relieve each other during long flights and is seldom used in bumpy weather and then only in emergencies. Referring to the author's remark that "The difficulties of a forced aeroplane landing in unsuitable country have not as a rule any parallel in a forced landing at sea, although other troubles arise in bad weather," Squadron Leader Maycock did not see exactly what was meant by that. He believed the author meant that the risks of landing in a rough sea were not so bad as landing in difficult country, but that the difficulties which followed were a serious matter for the machine; once having landed at sea, then the trouble started. He himself considered that unless one had extraordinarily bad luck, where both engines had absolutely broken down, or the weather was so bad that one was being blown away from land and one had to give up all hope, it it would be better to land at sea; he would prefer to be at sea anyway. He was an enthusiast on seaplanes and perhaps this helped him in the belief that there was not very much between them and heavy aeroplanes. He recognised, however, that there were still quite a number of things which needed improvement, such as, for instance, the question of corrosion, especially if metal hulls were adopted; there were a number of these points to be met before they could really consider them to be of real value for military and commercial purposes.

Mr. W. O. MANNING said that one thing which stood out clearly from the lecture was that what was wanted was a seaplane which could be controlled on the water as would a motor boat, would fly as well as the best aeroplane produced, and stand a big sea, and he thought there was hope that what was wanted could be obtained.

It is difficult to see how as much as 400-600lbs. of water can be absorbed in a flying boat, the larger of these weights being equivalent to over nine cubic feet, and it is difficult to avoid a suspicion that possibly there was some water left in one of the compartments of the hull when the machine was weighed.

Although we are very far from the ideal seaplane there are developments in progress which show promise of overcoming the difficulties referred to by the lecturer. Corrosion of metals especially should soon be a thing of the past.

He would like to emphasise the great value to seaplane design of the results obtained by the cruise of the four flying boats, under the command of Squadron Leader Maycock, and to express a hope that such cruises may be repeated.

In conclusion he would like to thank the lecturer for a paper which fills in a serious gap in the previously published information referring to seaplanes.

Mr. G. S. BAKER (National Physical Laboratory) said it was an advantage to those who had to deal with the design of these boats to hear what the users had to say. With regard to the author's statement that a long bow to the hull was a necessity in order to avoid diving if alighting steeply, he would like to know

what the author considered was the minimum angle at which a seaplane should come into contact with the water in a bad case, in order to avoid diving. Of course they could not cater for any angle, but this angle should be known more or less clearly, if a pilot is to avoid disaster when he made a not too serious mistake. He congratulated the author on the apparent alteration in his opinion since his (Mr. Baker's) paper was read before the Society a fortnight previously. He had thought, from the author's previous remarks, that he did not agree with him (Mr. Baker), but his opinion appeared to be moving in favour of the large flying boat in the future. The author, in speaking of controls, had mentioned using a " Servo " motor. This involved a good deal of extra weight. He had recently seen a rudder on a 10-knot ship worked with a wire no bigger than ¼-inch diameter, and he believed German designers were beginning to adopt the same system for their controls. He believed something on those lines would be devised for controlling large machines in the future, instead of the brute force arrangements in use at the present time.

With regard to the reference made to flexible and non-flexible hulls, these terms were wrongly used. There was no definite division of flexibility and non-flexibility between the " F " boats and the " P " boats in many respects. The difference between them came in in the way the hull was built to absorb forces. He had seen the bottom of the so-called rigid " F " boat, panting in and out a quarter of an inch, and he had been out on a " P " boat many times and had never seen such a movement, although that hull was called flexible and the " F " boat hull was called rigid. The difference lay in this, that whereas in the " P " boats any force was rapidly absorbed throughout a fairly *large area*, in the " F " boats that force was taken up by a comparatively small area, resulting in the production of big stresses. The forces were local and concentrated, but neither of these hulls broke due to any weakness or to want of flexibility of the main structure.

Squadron Leader R. M. HILL said that the author had startled him a little, because he had taken as the most important improvement in design the improvement of air control. There was no doubt in the mind of the landplane pilot that on the whole the landplane did not suffer from such disabilities as the seaplane; and that, because the designer did not have to cope with so many difficulties, the landplane was a little easier to handle generally.

In a seaplane the high thrust line and low C.G. contributed to a large change in longitudinal trim as the thrust varied; when, therefore, the pilot opened or closed his throttle he had to make an anticipatory movement of the control to prevent the seaplane suddenly pitching. With regard to the depressing tail, he thought it would be found that if they made the aeroplane or seaplane longitudinally stable, the C.G. would of necessity be relatively far forward; the tail plane would then have to be at a negative angle to the main planes, so that when the slip stream acted on it the forces tending to neutralise the effect of variation in thrust would be in the right direction.

Lately it had been found possible to balance the controls of large aircraft in new ways and thus to make them very much better than it was formerly anticipated they could be made. He expressed his great interest in the paper, and felt sure that the extraordinary lucidity which the author had shown in getting right at the heart of the difficulties made one confident that the development of the seaplane was in the very best hands.

Captain D. NICOLSON said that Wing Commander Cave-Browne-Cave had laid great stress on the sagging of the tail of some of the flying boats; this, he said, could easily be prevented. When he was assisting the late Major Linton Hope in the design of some of the hulls, they had saved as much as 500lbs. on the N.4 and about 250lbs. on the P.5 from the original weight given. This was partly done by cutting down the stringers to a minimum, and these were tapered

rather fine at the after end. Again, more stringers should have been carried further aft, the extra weight would have been very little and well within the calculated original weight specified.

With regard to towing, Captain Nicolson stated that he had had a good deal of experience in towing hydroplanes and flying boat hulls, and found the marine practice best by having a power boat behind the vessel being towed, as by this method all tendency to yawing would be stopped. If drags were used and a beam sea running, the drags always found their way over to the weather side, thus pulling the tow out of alignment.

Captain Nicolson stated that the amount of water absorbed by the hulls, as in the example quoted by Wing Commander Cave-Browne-Cave, was abnormal, and if the boats were not leaking it proved conclusively to him that the hulls were not kept properly. If the hulls were to be kept in very good condition the old varnish should be scraped off, or properly rubbed down and a new coat applied every month, or at least every two months. If this was too much work for the stations then the boats should be veloured once a year.

With regard to anchors, Captain Nicolson made many suggestions, amongst which he stated the canvas sea anchor was very light and yet effective.

There was one point not mentioned by the author, but which was of great interest, and that was the question of marine growth; and he would like to know if trouble had been experienced with such, as he had heard of many cases where in foreign waters the boats would hardly become unstuck after lying out for some time. If Commander Cave-Browne-Cave was faced with difficulties in this direction, Captain Nicolson thought the problem could be easily solved for home waters and would give the benefit of his experience if necessary.

Mr. A. Q. Cooper, speaking on the question of getting off from a rough sea, said that was very important, especially from the Service point of view. A machine which would be at sea perhaps for days could not keep in the air all the time, and if the machine could only get off from a moderate sea then its usefulness must be very materially restricted. He considered that a machine could get off a rough sea if it had sufficient power to rise quickly enough, and a machine which could use abnormally high power when getting off was very desirable.

Colonel S. Heckstall Smith, speaking as a sailor, referred to the author's remarks as to the value of having a central engine-room, his objection, however, being the danger of fire. In the very early days, when he was building motor boats and auxiliary motor boats, there was trouble in that way, and they had entirely got over it by keeping the carburettors outside the hull altogether. The difficulty of warming was got over by running the exhaust pipe alongside the induction pipe.

By keeping the carburettors outside and using long induction pipes there was no danger of fire, and further, he daresay it was luck, they actually got more revolutions out of the engine than when the carburettors were close to the engine. It is quite probable, however, that an actual improvement in power with some engines might be obtained, due to the large volume of atomised mixture on which the engine has to draw. The induction pipe which in fact gave the improved result was 15 feet long. The question of mooring was also interesting to him as a sailor. He had always found, with small racing yachts, say of ten tons displacement, where they wanted to keep weights down, that it was necessary to carry two small anchors to use in a tide-way rather than trust to one big one, because one anchor allows the ship to yaw, and swinging with the wind and tide may cause the anchor to trip. The yacht, of course, drops the anchors in the line of the tide and moors between them, frequently using a swivel to the anchor ropes or chains. Two small anchors might well be more

effective than one of the same weight as the two. With regard to keeping the hull well pumped out, he had found a form of diaphragm pump very light and effective and he had in fact installed such pumps in the first motor lifeboat which he had fitted with an engine—in this case, however, as he used two-cycle engines they lent themselves conveniently for the purpose, as all that was necessary was to couple the diaphragm pump direct to the crankcase, which gave required pulsation.

Squadron Leader WRIGHT (Air Ministry) said that the term seaworthiness was used rather loosely. In his opinion it seemed necessary to examine the meaning of this term more closely. In order to grasp its significance it is necessary to sub-divide the term into five headings, namely: (1) Taxiing under power; (2) drifting at sea with one or more engines stopped; (3) resting at moorings; (4) taking off; (5) landing. Each one of these sub-divisions required special consideration in the design of a machine; and the behaviour of a seaplane when on the water depended on a careful compromise of the requirements of these five conditions. Dealing with the first, "Taxiing under power," he said that the chief problem when taxiing in a rough sea was to avoid damage to propellers. Condition 4, "taking off," required propellers which would give a high efficiency at relatively low air speeds to enable quick acceleration on the water to be possible, but high propeller efficiency under these conditions required larger propeller diameters than would be necessary in an equivalent land machine; but, on the other hand, a large diameter meant small water clearance in the centre of thrust was not to be unduly high.

It will be seen, therefore, that a very careful compromise between conditions one and four has to be made. With regard to "drifting at sea," it was generally necessary to employ a sea anchor to keep the machine's head to wind as their ability to withstand heavy seas under these conditions depended to a great extent on the maintenance of the seaplane in this position. Riding at moorings was a simpler problem than might be imagined, and Squadron Leader Maycock had spoken of the ability of seaplanes to ride out a gale provided that adequate precautions were taken to prevent them flying at their moorings.

"Taking off" required consideration of two conditions, namely, (A) taking off in a sea with a strong wind blowing and (B) taking off in a swell with no wind. Condition (B) was by far the most difficult state of affairs. Low weight per h.p. to provide quick acceleration is necessary to achieve this successfully. Landing in a rough sea called for a planing bottom of sharp "V" in the cross section if risk of damage to the hull is to be avoided. Air controllability with engines off is also an important factor as it is necessary to place the machine in the best position just before contact with the water is made. It is hoped that an opportunity will be available to analyse the problem of seaworthiness and obtain such data as is possible to enable the task of the designer in making this compromise easier.

Wing Commander CAVE-BROWNE-CAVE, replying to the discussion, said Mr. Narbeth had drawn a clear distinction between the seas experienced in the North Sea in winter and those experienced during the cruise last summer. The seas met with on that cruise, as a matter of fact, were really big. The weather was most difficult, there being bad mists and big seas and every form of unfavourable weather, so that from the point of view of demonstrating the seaworthiness and general suitability of the boats under all conditions the weather did everything required. Squadron Leader Maycock had drawn attention to the fact that he (Wing Commander Cave) had been pessimistic about the qualities of flying boats. One did not address the Royal Aeronautical Society in a mere eulogy; what interested such a Society was a discussion of the difficulties which existed and the ways of trying to get over them. This led to valuable suggestions like some of those made that evening. He had said in the paper that flying

boats were heavy to control. They certainly were heavy to control "in bumpy weather," a reservation which Squadron Leader Maycock had apparently missed. As to landing in unsuitable country not being parallel to landing in a rough sea, both seaplanes and aeroplanes got into difficulties in bad weather, but an aeroplane often got into difficulties in the case of a forced landing even in the best weather; for instance, when landing in a small field.

Mr. Manning had explained that what was wanted was something which was as good as a motor boat on the water and was a perfect flying machine. He himself did not think a motor boat was good enough; some motor boats were terrible in a sea in which existing seaplanes were quite comfortable, and he was perfectly certain that the Development Squadron could not have taken any motor boat through what those flying boats experienced. We wanted to go further than that. Mr. Manning had also asked whether, in regard to the water taken up, the compartments in the bottom were clear. They were as clear as it was possible to make them under practical conditions. They could not dry them out completely, but there was no casual water lying about.

Mr. Baker had asked what was the minimum angle at which it was thought desirable that the boat should be able to land. That was a very difficult question to answer, but he would endeavour to get a consensus of opinion among pilots in that connection. It was exactly the kind of point he certainly would not presume to pronounce upon. Mr. Baker had pointed out that a long bow was not really necessary in order to avoid diving. But why then did the long bow exist? From the flying point of view, very great benefit would result from reducing the length of bow. The author pointed out that shock could only be absorbed if there was deflection and he inferred from Mr. Baker's remarks that the deflection was less concentrated in the "P" than in the "F" type. He was very sorry to find that Mr. Baker had misunderstood what he had intended to convey at the last meeting of the Society. Mr. Baker apparently thought that he (Wing Commander Cave) did not think that the big flying boat was the type of big machine which would persist. As a matter of fact, he most certainly did think that it would. He believed that the flying boat was not only the big type for future marine aircraft, but he thought it was the most promising form of big aeroplane of any sort or kind. The point on which he had differed from Mr. Baker in the last lecture was whether one would make one's ocean passages in a flying boat or in an airship. The Society knew that he had definite views about airships. He did think that for passages of 1,500 and 2,000 miles or more the advantage was entirely with the airship. It was most interesting to hear what Mr. Baker had said about the rigidity of both types of boat at the step. That was a point that he had never heard expressed by any authority previously. It certainly appeared correct.

Captain Nicolson had mentioned the question of the stiffness of the tail of the Linton-Hope hulls. He quite realised that they could make the tail as stiff as they liked, but at the expense of weight. His contention was that if they carried the tail on a fuselage, or between two fuselages, they would make the tail rigid for less weight than would be necessary to give the same rigidity if they supported it overhung above the top of the hull. Captain Nicolson had also suggested that a motor boat towed astern of a flying boat would make her easier to tow. That meant using two motor boats, and he believed that every seaplane pilot regarded a motor boat in the neighbourhood of his machine as a potential danger. As to the types of anchors, the sea anchors used at present were perfectly satisfactory, and he did not think they could be improved very much. They held well and were of purely nominal weight. Those which held on to the sea bottom and prevented the machine moving at all were the difficulty. He had been badly startled when Captain Nicolson had suggested that the machines should be varnished once a month. With regard to scraping off the old varnish

before putting the new on, it was not practicable to do that on the inside of the boat. A great deal of water, he believed, was absorbed from the inner surface. Making the boats watertight would only be achieved by a method which could be carried out with a reasonable amount of care during the progress of actual operations, *i.e.*, any complicated business such as re-varnishing once a month was absolutely out of the question. All varnishes were permeable to gradual diffusion of moisture as was shown by the way the wood swelled and became tight. The majority of the absorbed weight was therefore unavoidable in a wood hull. So far as he knew, no trouble had been experienced with marine growths on the bottoms of the boats. (Later Note.—Considerable trouble was experienced in parts of the Mediterranean at certain seasons. Scraping once a month had sometimes proved necessary.)

Mr. Heckstall Smith had made suggestions which brought out the value of such discussions. His method of putting carburettors outside the boat appeared to him (Wing Commander Cave) a complete answer to the difficulty which was looked upon as a very serious one, that of putting the engines inside the boat. The fact that Mr. Heckstall Smith had managed to make a 15ft. induction pipe work was most interesting. He agreed also with regard to the two small anchors, and thought that probably the reason the seaplanes did not carry two small anchors instead of one was the fact that a tangle might exist in the cockpit in the absence of a proper arrangement of hawse pipes.

Squadron Leader Wright had spoken with regard to seaworthiness. That was an extremely complicated matter, and the only way of tackling it systematically was by dividing it into sub-headings in such a way as had been mentioned. They had had two or three discussions at Grain on the question of seaworthiness, and on every occasion those discussions could have gone on so long as the time lasted. It was a most complicated and interesting business.

A very hearty vote of thanks was accorded Wing Commander Cave at the conclusion of the discussion.

Mr. Oswald Short (*communicated*): Owing to being so far from London I regret being unable to attend this very interesting lecture, but having read the advance proof, I should like to congratulate the lecturer on the fact of his having presented in a simple and straightforward manner information which is of the greatest value to designers of flying boats.

I should like to make the following comments:—

I agree with the suggestion made by the lecturer that a rigid hull of the same external form as the P.5 might have done just as well and would not have led to trouble with the step. One cannot help but feel that any considerable movement of the hull bottom, considering the method of manufacture, must ultimately lead to trouble by chafing of the waterproof lining and by loosening of the fastenings in lateral stiffeners. The trouble with the rigid step is a case in point. To absorb the vertical momentum of a boat on impact with water in a satisfactory manner, a considerable amount of cushioning movement is necessary, and there appears no reason why the whole of the upper structure should not be resiliently attached to the boat hull in a similar manner to the attachment of seaplane floats.

With regard to the floating dock referred to by the lecturer, I am very gratified to note that a scheme which is very similar to one I urged upon the Admiralty and of which I prepared plans and a working model so early as 1913, and which was exhibited to Mr. Winston Churchill and others in that year, has at last been carried into practice and has proved its usefulness.

LEONARDO DA VINCI'S MANUSCRIPT ON THE FLIGHT OF BIRDS

BY IVOR B. HART, B.SC., A.F.R.AE.S.

Introduction

The manuscript by Leonardo da Vinci, of which a complete English translation is here offered (so far as the writer is aware, for the first time), is known as the "Codice sul Volo degli Uccelli e Varie Altre Materie" (Codex on the flight of birds and other matters). It is a small note-book of some 30 pages, and measures about 8.4 inches by 6 inches. It was written at Florence in the year 1505, between March 14th* and April 15th.† A close study of this manuscript has been made by G. Piumati‡ in a very fine edition containing an excellent facsimile of the original note-book, together with (*a*) a printed copy folio by folio of the old Italian script in which it was written, (*b*) a rendering into modern Italian, and (*c*) a French translation by C. Ravaisson-Mollien.

The reading of Leonardo da Vinci's manuscript has been a task of enormous difficulty with which is honourably associated the names of a small band of enthusiastic students, chief among whom may be mentioned J. Paul Richter, G. Piumati and C. Ravaisson-Mollien. Leonardo, from the time he was twenty years of age onwards, invariably wrote in a manner calculated to confound his would-be readers. We may summarise the characteristics of his script under four heads. (1) He wrote from right to left after the fashion of the Semitic group of languages, (2) his handwriting was of the kind known as "mirrored," *i.e.*, reversed in a manner such as would be produced by looking at a normal script through a mirror, (3) he employed an elaborate scheme of abbreviations, and (4) he omitted the use of punctuation. It is accordingly much to the credit of the patient workers to whom reference has been made above that, in spite of these difficulties, the writings of this great genius of the Italian Renaissance have been rendered available to the world of science and letters generally.

It is only within comparatively recent times that the vast collection of notes and sketches accumulated by Leonardo da Vinci has been given the attention it deserves. Unfortunately circumstances were such that after his death they were lost sight of, and it was only after the lapse of centuries that they once again came to light. This loss was a serious misfortune to science. Leonardo's work was in itself so fruitful and varied, and his outlook on nature was so vastly superior to those about him, that if only those who followed after him could have had access to his writings, and to his many anticipations of later discoveries in different fields of intellectual activity, there is no doubt that the course of scientific history would have been materially different in a number of important directions.

When da Vinci died at Amboise in the south of France, in 1519, he left a will bequeathing his manuscripts, instruments, paintings and sketches to the friend of his old age, Francesco Melzi, who was with him at his death. Melzi returned to his home in Milan, carrying this bequest with him. Here, in his villa at Vaprio, the manuscripts were guarded with tender and jealous care for the next

* Amoretti, "Memorie storiche su la vita, gli studi, e le opere di Leonardo da Vinci," Milan, 1840, p. 99.

† See M.S., folio 18 v., below.

‡ "Codice sul Volo degli Uccelli e Varie Altre Materie," Publicato da Teodoro Sabachnikoff. Trascrizioni e note di Giovanni Piumati, Paris, 1893.

fifty years. Melzi however died in 1570, and it is from this time onwards that the tragic dispersal of the manuscripts may be said to have taken place. Attempts which, during Melzi's lifetime, had been made to obtain access to the note-books (notably by Alphonso I. of Ferrara and by Vasari, Leonardo's earliest biographer), and which had failed, were now renewed, this time with success.

Francesco's heirs were not interested in science, art, or letters, and when the family tutor, Lelio Gavardi di Asola, conceived the idea of disposing of some thirteen volumes of the manuscripts, he met with little difficulty. However, the Grand Duke Francesco of Florence, to whom it was intended to sell these volumes, died at this juncture, and Lelio Gavardi took them instead to Pisa. Fortunately, the man whom he approached, Ambrosio Mazzenta,* dissuaded Gavardi from pursuing his dishonest intentions, and the latter left the volumes with Mazzenta to be restored to the Melzi family. Orazio Melzi, the rightful owner, in his lack of interest, however, not only permitted Mazzenta to keep the volumes as a reward for his trouble, but told him further that he could help himself to any of the remaining bundles of matter lying about the attics at Valprio.

Others, too, had heard of the spoils to be gathered in from these attics, and they readily availed themselves of Orazio's free invitations of "help yourself." Amongst those seeking to acquire Leonardo's manuscripts was Pompeo Leoni, a sculptor and friend of Philip I. of Spain. It was his plan to seek favour from his royal master in exchange for these manuscripts, and accordingly he approached Orazio Melzi with promises of reward from King Philip if he would secure the return of the thirteen volumes given to Mazzenta. As it happened, Ambrosio Mazzenta had by now (1590) taken vows with the Barnabite Order, and had passed on his thirteen volumes to his brother Guido. It was Guido, therefore, who was approached by Orazio Melzi, and as a result seven of the volumes (one of which contained the small note-book on the flight of birds) were returned and handed on to Leoni. Of the remaining six, three were subsequently acquired by Leoni on the death of one of the Mazzentas, and another volume was given in 1603 to Cardinal Federico Borromeo, the founder of the famous Ambrosian Library at Milan (1609). The remaining two have long been completely lost sight of, although we know that one of them was given to Ambrogio Figino, a painter, and has been traced through various owners up to 1759; and the other was given to Duke Charles Emmanuel of Savoy, and was probably destroyed in an outbreak of fire at the Royal Library at Turin about the year 1667.

Actually Pompeo Leoni did not give his manuscripts to King Philip II. of Spain. Not only did he keep them himself until his death, but he went so far as to cut out portions of them to form, together with a number of loose drawings, a single large volume which, on account of its size (it contains 402 sheets and more than 1,700 drawings and sketches), he called the "Codice Atlantico" ("Codex Atlanticus"). Leoni died in 1610 and the manuscripts passed into the possession of his heir, Cleodoro Calchi, who in his turn sold some of them, including the Codex Atlanticus, to S. Galeazzo Arconati in 1625. Arconati kept these until 1636, in which year he presented to the Ambrosian Library at Milan the Codex Atlanticus together with eleven other volumes of da Vinci's manuscripts, thus making, together with the original volume presented by the founder of the library in 1603, a collection of thirteen volumes. To these a further one was added in 1647 by Count Orazio Archinto. One was probably subsequently stolen, since its description coincides with that of a volume bought in 1750 by Carlo Trivulzio. The period of restoration may now be said to have begun.

In Arconati's deed of gift, making over these volumes to the library, we find

* The chief source of our knowledge regarding the history of these manuscripts is derived from "Alcune memorie di Giovanni Ambrogio Mazzenta intorno a Leonardo da Vinci e a suoi manoscritti, con illustrazioni del Prof. Gilberto Govi" (Il Buonarroti).

the first authentic record of the existence of the manuscript on the flight of birds. Inside the cover of the third volume of the gift we read: "At the end of this book there is another little volume of various mathematical figures and of birds of eighteen pages sewn in the same page in parchment."*

For the next chapter in the story of the wanderings of these manuscripts we come to the year 1796, when Napoleon Buonaparte, in his capacity of chief of the French army in Italy, commandeered various works of art, including the thirteen volumes of Leonardo's manuscripts, and these were transported to the library of the Institute of France in Paris, where according to the official records they arrived on the 25th of November.

Here the volumes were carefully examined by Venturi and to him the world is indebted for the first real description of the manuscripts.† For purposes of reference, Venturi assigned to each manuscript a capital letter beginning with A, and this nomenclature has since received general acceptance.

As a result of political changes, in the year 1815 representations were made to France on behalf of Lombardy for the return of da Vinci's manuscripts to Milan. For some reason or other, although France consented to this restoration, only the Codex Atlanticus (which alone of all these volumes was housed in the Bibliothèque Nationale instead of in the library of the Institute of France) was returned to the Ambrosian Library, and the remainder have been kept in Paris ever since.

The particular volume to which we have already referred as containing an appendix of the note-book on the flight of birds was lettered B in Venturi's series. Venturi, however, considered the note-book of sufficient importance to be regarded as a fourteenth volume in itself and he lettered it N accordingly.

The subsequent history of our small note-book is interesting in the extreme. In the year 1848 it was discovered that certain manuscripts, and amongst them the appendix to manuscript B, were missing. That they were stolen is fairly certain, and that the culprit was Prof. Giacomo Libri is indicated first by the fact that prior to 1848 he had had frequent access to these manuscripts and, secondly, that he was in undoubted possession of them in 1867. In December of that year Count Giacomo Manzoni of Lugo, whilst on a visit to Florence, was shown the manuscript amongst others "acquired" by Libri, and bought it from him a year later. Libri also disposed of some of the manuscripts to Lord Ashburnham in England, but these latter were returned to France in 1888.

On the death of Count Manzoni, in 1889, the note-book "On the Flight of Birds" passed to his heirs, and from them it was acquired in 1892 by M. Theodor Sabachnikoff, and the volume associated with his name and that of Piumati is the honourable result.

The note-book has since passed into the possession of the Library of Turin.

The genuineness of the manuscript on the flight of birds is beyond all dispute. Not only does it bear all the unmistakable characteristics of Leonardo da Vinci's general work, script, mode of presentation and style, but the note-book is autographed with the writer's name on the cover. Such doubts as have been thrown by M. Ludwig,‡ not so much upon the authorship as upon the originality of the paging as it at present exists, have been effectively disposed of by Piumati.§ Although a second set of page numbers has been written in by someone subsequent to the original writer, Leonardo's numbering remains intact and unmistakable.

---

* I Manoscritti di Leonardo da Vinci, "Codice sul Volo degli Uccelli," etc., Pubblicato da Teodoro Sabachnikoff. Trascrizioni e note di Giovanni Piumati (pp. 28 and 29), Paris, 1893.

† J. B. Venturi, "Essai sur les ouvrages physico-mathematiques de Leonard de Vinci," Paris, 1796.

‡ M. Ludwig, "Leonardo da Vinci, Das Buch von der Malerei," II. Band, p. 5.

§ Sabachnikoff, "Sul Volo degli Uccelli," etc., p. 35.

The reason for this duplication of numbering is to be found in the fact that the manuscript on the flight of birds is not complete. Comparison with Venturi* and Amoretti,† who were the first translators of some of the passages from Leonardo's works, show clearly that pages which were in the note-book originally are not there now. The pages in question are folios 1, 2, 10 and 17. Page 18 was also originally missing, but happily was rediscovered in England and secured by M. Th. Sabachnikoff in time to be included as an appendix to his book.‡ Its identity was assured from its dimensions and general agreement in every respect with the remainder of the note-book. The number of the page, absent through mutilation, has been identified from references to Venturi and Amoretti.

In submitting this English rendering, the writer desires to record the valuable assistance of his colleague, Mr. E. D. West, who ungrudgingly placed his knowledge and advice at the writer's service. It should be remarked that although the primary purpose of the translation is to further the study of Leonardo da Vinci's contributions to aeronautical science, every note in the manuscript has been included, even though not relevant to this primary purpose. Not only is this done for the sake of completeness, but it is also hoped that the result may be of interest to students of scientific history in general, and to students of Leonardo da Vinci in particular. It is a matter for regret that it has not been found possible to include all the diagrams and sketches in the original manuscript. Nevertheless, all those which seriously bear upon the text are given, and for assistance in the preparation of these the writer desires to express his indebtedness to his colleague, Mr. W. Laidler.

The writer's grateful thanks are due, finally, to Dr. Charles Singer, at whose suggestion these studies of Leonardo da Vinci were undertaken, and whose encouragement and helpful advice has contributed very materially to their achievement.

"ON THE FLIGHT OF BIRDS."

TRANSLATION OF A MS. BY LEONARDO DA VINCI.

NOTE.—*In the translation, text enclosed in brackets thus* [ ] *has been interpolated by the author; text enclosed in brackets thus* ( ) *denotes matter written in by Leonardo and then erased.*

[Cover—Interior [1].]

To stamp medals.—Boil emery mixed with brandy, or iron-scales with vinegar or ashes of walnut leaves, or ashes of straw finely triturated.

The diamond is crushed enveloped (within) in lead, and beaten with a hammer, and the lead spread out several times, and refolded (and *r*) and kept wrapped in paper so that the powder be not spilled and then melt the lead and the powder will rise to the surface of the molten lead, which may be then rubbed between two steel plates, so that it powder well, and then wash it with nitric acid, and the blackness of the iron will dissolve and leave the powder clean.

Emery in large pieces is broken by putting it on a cloth folded (in) many times and then striking it sideways with the hammer; thus it will break into flakes, little by little and then is easily crushed; if you put it on an anvil, you will never break it, being so large.

Who powders enamel, should do so on plates of tempered steel, with a steel pestle, and then put it in nitric acid, which dissolves all the steel which is used up and mixed with this enamel making it black, so that it remains purified and clean; if you powder it on porphyry, this porphyry wastes, is mixed with the

* J. B. Venturi, "Essai sur les ouvrages," etc., p. 18.
† Amoretti, "Memorie storiche su la vita, gli studi, e le opere di Leonardo da Vinci," Milan, 1804, p. 99.
‡ Sabachnikoff, p. 147.

enamel and spoils it, and nitric acid will never remove it (*s*), because it is not able to dissolve such porphyry.

It you wish to make a beautiful blue colour, resolve the enamel made with tartar and then remove the salt. Brass vitrified makes a beautiful red.

[Fol. 3—*r*.]

Instrumental or rather mechanical science is very noble, and useful beyond (*p*) all others, seeing that, by its means, all animated bodies which have movement, perform their operations; which movements proceed from their centre of gravity, which is situated at the centre, except with unequal weights, and the latter has paucity or abundance of muscles, and also, lever and counter-lever.

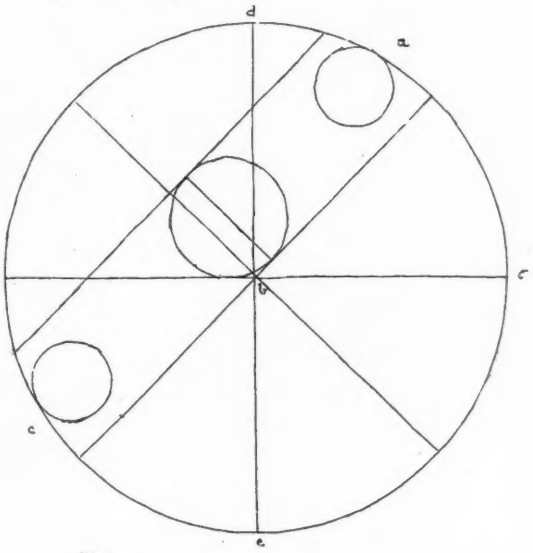


FIG. 1.

Here the balance *a b c* [Figs. 1 and 2] has more space in *b a* than *b c*, and it would appear that it also, with weights attached to its extremities would, after several oscillations, stop at the place of equality.

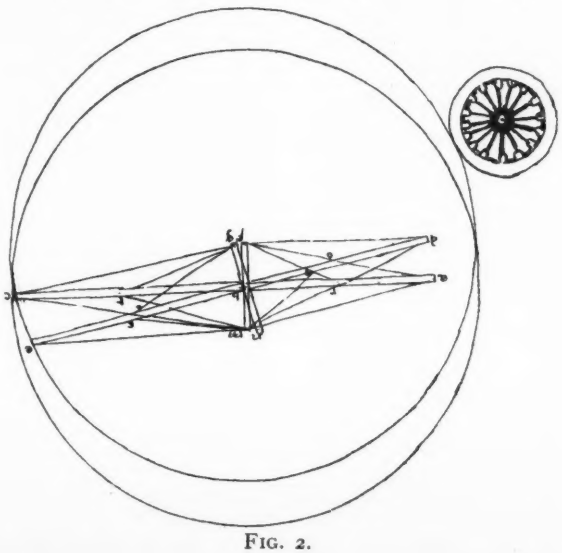
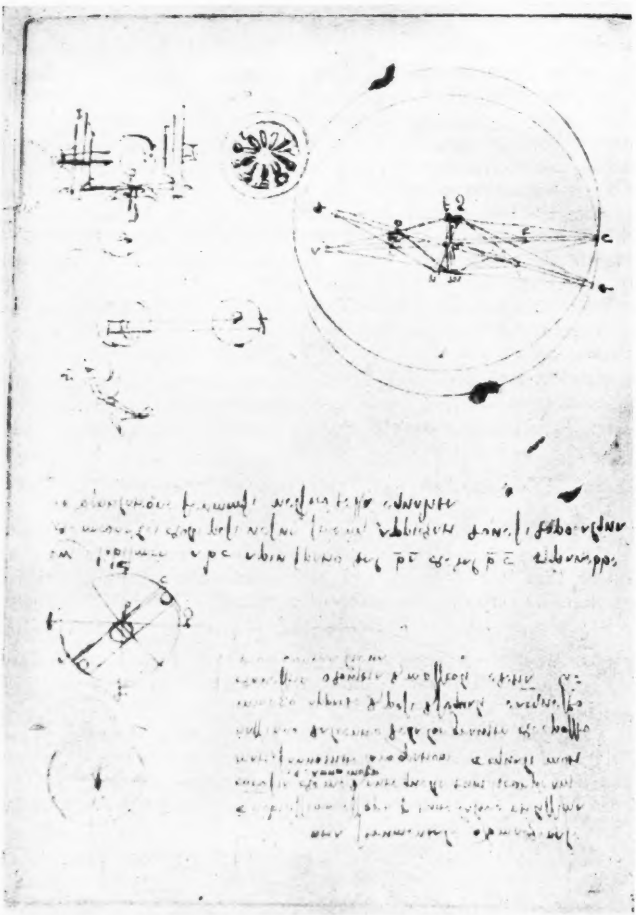
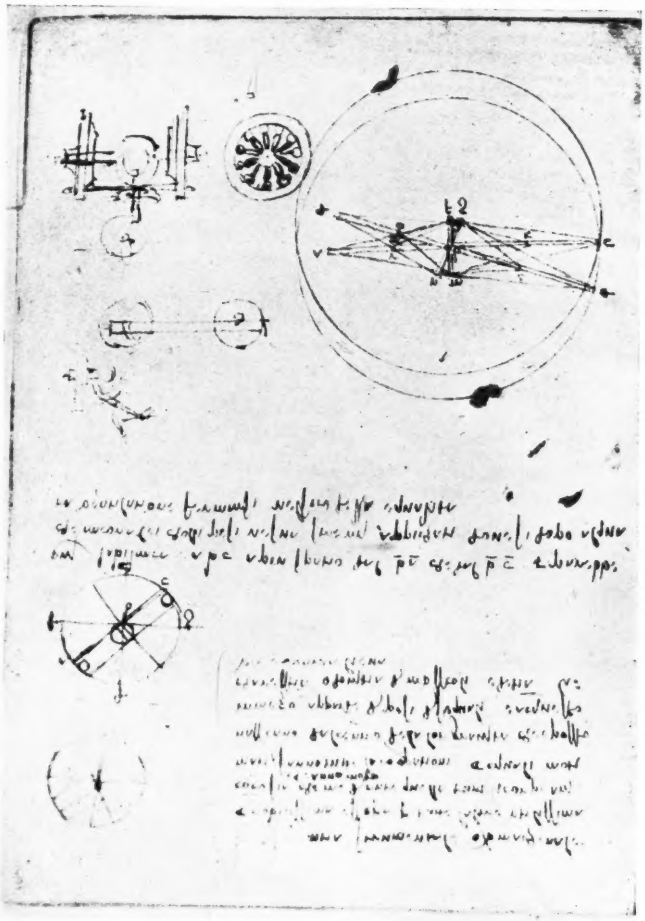
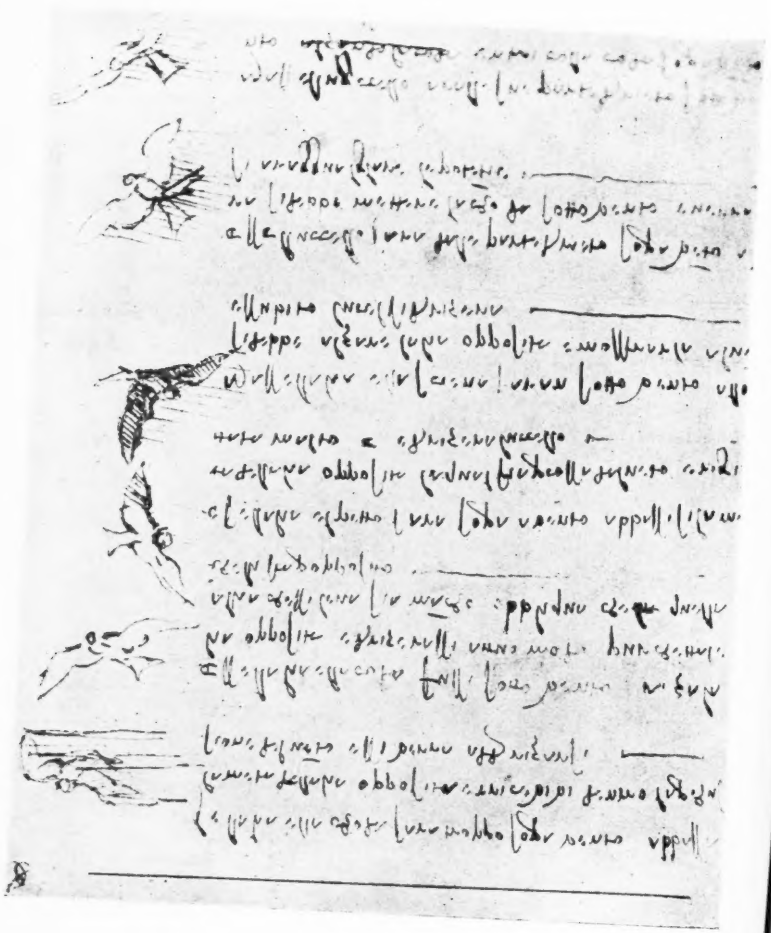
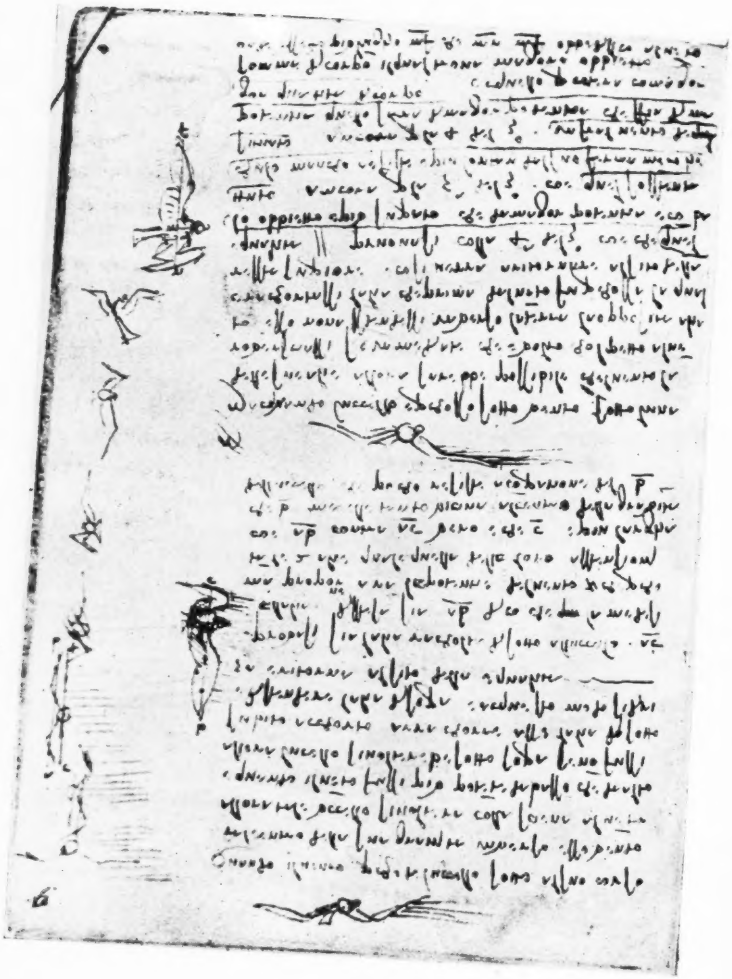


FIG. 2.









[Fol. 3—*v.*]

Different figures give in their obliquity different weights.

(If the rod (equipoised) is (*mo* fixed) able to revolve with one of its extremities round its other extremity. . . . The end of the rod will be prevented from revolv(ing) round its other extremity, to which will be fixed a straight cord, which will be attached to the opposite end under the centre of the above mentioned revolution.) At the end of this rod circular movement will be prevented round its other extremity by this cord, which in a straight line is fixed under the centre of the said circle and is attached to the extremity of the rod. As if the rod were the line *p q* [Figs. 3 and 4] and the end which is prevented from moving in a circle *q m* be the end *q*, and the straight cord attached under the centre (of) the circle, be *o q*, I say that the end (*q*) *q* of the rod will never reach the point *m*, if the cord does not break.

It is proved as follows: If the rod *p q* has to move its extremity *q* to *m*, it will follow the arc *q m* because such a rod is the radius of the circle *q m s*: and the stretched cord, *o q*, will not be able to follow the extremity of the rod from *q* to *m* unless its length increases by the part *n m*, because it also is the radius of its circle *q n s*: thence it is obvious that *q* cannot move.

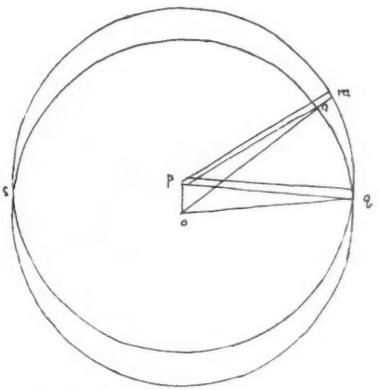


FIG. 3.

The objector says here, that the rod *p m* will bend until it makes with its extremities the length of the cord on [which it] will en(t)er.

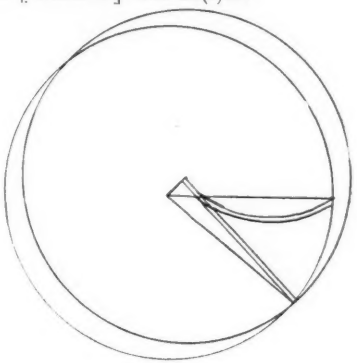


FIG. 4.

Here it is necessary, either that the cord should break so as to have the length of the rod or that the rod should bend so as to have the length of the cord.

[*The text below follows after the bottom of fol.* 4*r.*]

at *a* and gives 2lbs. at *c* because *a* itself also is centre of the revolution: therefore 1lb. at *b* pulls 2 at *a* and pushes 2 at *c* which makes 4lbs.

[Fol. 4 recto.]

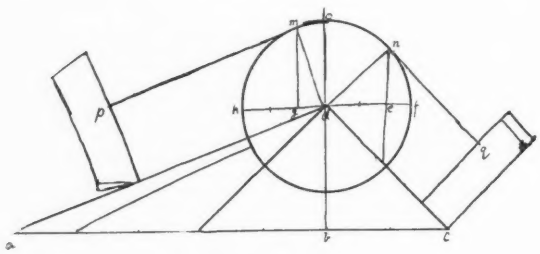


FIG. 5.

The weight *q* [Fig. 5], because of the right-angle *n*, above *d f*, at the point *e*, weighs 2/3 of its natural weight, which was 3lbs.; and is a force of 2lbs.; the weight *p*, which was also 3lbs., is a force of 1lb.; because of *m*, right-angle on the line *h d* at the point *g*, then we have here one pound against 2lbs. And because of the obliques *d a* and *d c*, on which the weights rest, which are not in the same proportion as these weights, that is to say, the one double the other, as the said weights their gravities change their nature, because the obliquity *d a* exceeds the obliquity *d c*, or contains the obliquity *d c* two and a half times, as *a b* shows with *b c*, their bases, and comes to rest in the double sesquilateral proportion, and that of the weights was in double proportion, therefore the excess of the greater obliquity over the less is 1 and ½; so that if the weights were, say 3 on each side they would rest in *d a*. . . .

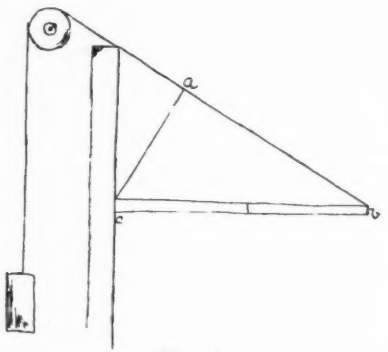


FIG. 6.

c [Fig. 6] is the pivot or centre of revolution and because *a c* is half the lever *c b*, one pound at *c* gives a force of 2 pounds.

[*Continued on previous page.*]

[Fol. 4 verso.]

FIG. 7.

I ask in which part of the undersurface of the width of the bird, the wing presses the air more than in any part of the length of the wings. [Fig. 7.]

All bodies which do not bend, though they may be each in itself, of different sizes and weights, they will exert equal pressures on all of the supports that are equally distant from the centre of gravity, this centre being at the middle of the substance of such a body. [Fig. 9.]

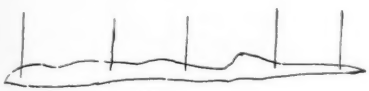


FIG. 9.

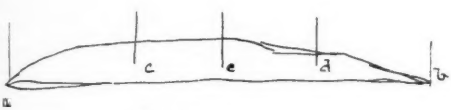


FIG. 10.

One proves how the above mentioned weight exerts equal pressure on its supports: let us assume that it is 4lbs. (I say) and that it is sustained by the support *a b*. I say that the body being unhindered in its fall except by the two supports *a b*, that these supports will sustain equal parts of this weight that is to say 2 and 2 and the same thing would apply to the 2 supports *c d*, if the 3 other supports were not there: and if the middle one at *e* only remained it would support the whole of the weight. [Fig. 10.]

FIG. 8.

Those feathers that are farthest from their points of attachment will be the most flexible. Therefore, the tips of the feathers of the wings will always be higher than their roots, so that we may reasonably say that the bones of the wing will always be lower in the depression of the wings than any part of the wing: and in the elevation these wing bones will be higher than any part of the wing. Because the heavier portion always guides the movement. [Fig. 8.]

But if the said body be flexible with different sizes (volumes) and weights still let the centre of gravity be at the centre of the substance it does not follow that the support which is nearest to the centre of gravity or to another inequality of gravity may not be more charged with weight than that which is over some lighter portions.

[Fol. 6 [5] *r.*]

A man with wings should be free from the waist upwards in order to balance himself as he does in a boat in order that his centre of gravity and that of the instrument might be able to balance and change when necessity required it according to the change in the centre of its resistance.

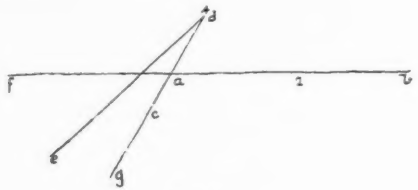


FIG. 12.

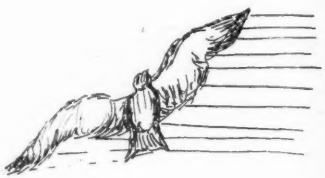


FIG. 11.

(Falling.) The bird being in the act of falling in the direction of its open wings [Fig. 11] with a force of 4 and the wind which strikes it underneath with a force of 2 makes its course straight: we will say then that the descent of such a bird will be by the mean line between the level of the course of the wind and the obliquity in which the bird was with the force 4. As: let the obliquity of such a bird be the line *a d c*, and let the wind be *b a*; I say, if the bird *a d c* had a force 4 and the wind *b a* had a force 2 that the bird would not go in the direction of the wind (either) in *f* nor by its obliquity in *g* but would fall by the mean line *a e* [Fig. 12]; and one proves it thus.

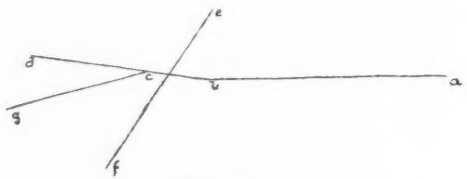


FIG. 13.

And if a bird make such an oblique descent [Fig. 13] with a force of 4 and if the wind that follows it have a force of 8. . . .

FIG 14.

When the bird wishes to turn to the right or the left by beating its wings then it will beat lower with the wing on the side to which it wishes to turn and thus *the bird will turn the movement behind the impetus (élan) of the wing which moves most.* [Fig. 14.]

[*Continued in Fol.* 6 [5] *recto.*]

[Fol. 6 [5] *v.*]

and makes the reflex movement under the wind on the opposite side.

When the bird by the beating of its wings wishes to rise, it raises the shoulders and it beats the points of the wings toward itself, and so condenses the air which lies between the points of the wings and the breast of the bird, the tension of which lifts up the bird.

The kite and other birds that move their wings very little seek the air currents, and when the wind is blowing high up then they will be seen at a great height and if the wind blows low down they remain low.

When there is little wind the kite beats several times with its wings during flight so that it may rise and obtain impetus, with which impetus inclining a little it goes a long distance without beating its wings; and when it has dropped [vol-planed] somewhat it repeats the movements and so successively: and this drop without beating the wings serves as a means of repose in the air after fatigue of the said beating of the wings. All birds that fly by spasms raise themselves by the beating of the wings and when they come down [vol-plane] they rest because they do not beat with their wings in descending.

[Fol. 7 [6] *r.*]

Concerning the 4 movements reflex and incident with varying aspects of the wind made by birds.

The oblique descent of birds, being made against the wind will be made under the wind and their reflex movement will be made on the wind.

But if such an incident [downward] movement is made to the east, the wind blowing from the north, then the north wing [upward] will remain under the wind, and in the reflex movement will do the same, so that at the end of this reflection the bird will find itself with its front to the north.

And if the wind descend to the south the north wind prevailing, it will make its descent on the wind, and its reflex motion will be under the wind: but this gives rise to a long discussion, which will be given in its due place because here it would appear that the bird would not be able to make a reflex movement.

When the bird makes its reflex movement against and on the wind then it will rise much more than it should from its natural impetus, seeing that it has the assistance of the wind which entering under it, serves as a wedge. But when it has completed its rise it will have used up its impetus and there will remain only the assistance of the wind which would turn it upside down because it strikes it on the breast and if it did not depress the right or left wing which will cause it to turn to the right or left, descending in a semi-circle.

[Fol. 7 [6] *v.*]

The movement of the bird ought always to be above the clouds lest the wing should be moistened to disclose a broader view and to avoid the peril of wind revolutions among mountain gorges, which are always full of whirlings and turnings of the winds. Beyond that, if the bird should turn somersault, you would have more time for righting it, with the directions already given before it reaches the ground.

If the point of the wing be struck by the wind and this wind enter under such a point, then the bird would be liable to be upset unless it use one of two remedies, that is to say: either that it force suddenly such a point under the wind or that it lower the opposite wing, from the middle on.

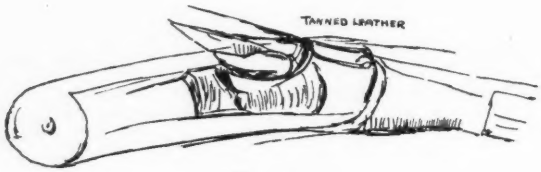


FIG. 15.

a b c d [Fig. 16] are 4 upper nerves to raise the wing (*b*) and act as strongly as the lower nerves *e f g h* on account of the overturning of the bird so that they might resist above as below although a single one of tanned leather thick and wide [Fig. 15] might perchance suffice; however, in the end, we must leave that to experience.

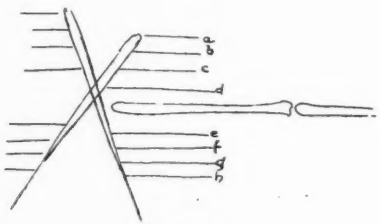


FIG. 16.

[Fol. 8 [7] *r.*]

The said bird ought, with the assistance of the wind to rise to a great height, and that will be its safety, even should it experience all the above mentioned revolutions, it has time enough to recover its balance provided that its limbs be very strong so that they may safely resist the fury and vigour of the descent with the above mentioned defences, its joints of strong tanned leather and its nerves [sinews] of raw silk cord of great strength; and let not anyone hamper himself with fittings of iron, because they burst easily in twisting, or waste away, for which reason they are not to be used.

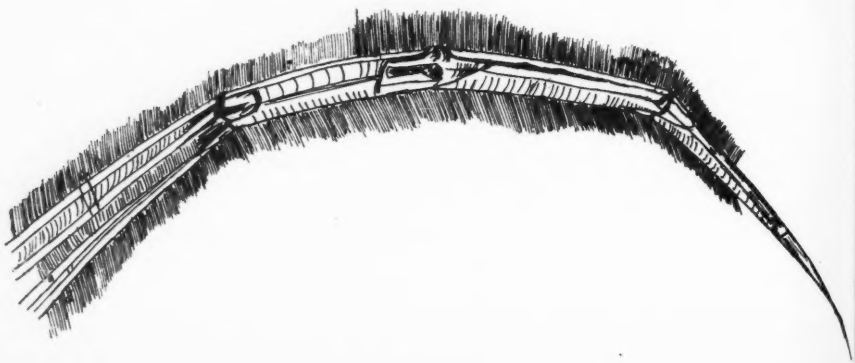


FIG. 17.

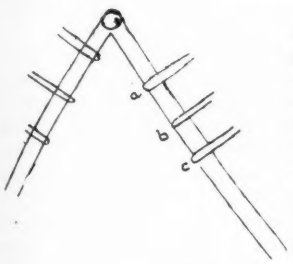


FIG. 18.

The nerve [sinew] *a* [Fig. 17] serving to stretch out the wing, should be of thick tanned leather, so that if the bird should be turned upside down, it would be able to overcome the fury of the wind which would strike in the wing and tend to close it, because that would cause the ruin of such a bird; but for greater security you will make precisely the same nerve outside as inside, and you will be beyond all suspicion and peril.

a b c [Fig. 18] are the attachments of the nerves of the 3 junctions of the fingers of the wings; *d* is the position of the motor of the lever *a d* which moves the wing.

[Fol. 8 [7] *r*.]

When the edge of the point of the wing is opposed to the edge of the wind for an instant, I put this wing under or on this edge of the wind and the same thing happens to the point or sides of the tail, and similarly to the shaft of the shoulders of the wing.

The descent of a bird will be always by that (part *w*) extremity which will be nearest to its centre of gravity.

The heaviest part of a bird descending will always be in front of its centre of resistance.

3rd. When without the assistance of the wind the bird remains in the air without beating its wings, in the position of equilibrium this shows that the centre of gravity is concentric with the centre of resistance.

4th. The heaviest part of the bird which descends with the head underneath, will never be above or level with the height of the lightest part.

If the bird fall tail first, by throwing the tail back it will restore itself to the place of equilibrium, and if it throws it forward it will overturn itself.

1st. When the bird which is in the position of equilibrium shall act so that the centre of resistance of the wings be behind the centre of gravity, then such a bird will descend head first.

2nd. And that bird which being in a position of equilibrium shall have the centre of resistance of the wings more forward than the centre of gravity of the bird then such a bird will fall with the tail turned towards the ground.

[Fol. 9 [8] *r*.]

If the wing and the tail are too much on the wind, lower halt the opposite wing, and therewith receive the force of the wind and equilibrium will be restored.

And if the wing and the tail were under the wind raise the opposite wing and it will be corrected to your desire, provided that such a wing as is raised be less oblique than (the) that which is opposite to it.

And if the wing and the breast are on the wind, one must depress half the opposite wing, which will be struck by the wind and forced upwards which will right itself.

And if the bird is so that its hind quarters are on the wind, then the tail ought to be forced under the wind, and thus one will be able to equalise the powers.

But if the bird has its hind quarters under the wind (raising the tail) let it enter with the tail on the wind, and it will right itself.

[Fol. 9 [8] *v.*]

When the bird is on the wind turning the beak with the bust (*s*) to the wind then the bird would be turned over by the wind, if it had not depressed the tail, and received in the tail a large portion of the wind: thus doing it cannot be turned over. One proves it by the first of the mechanical elements which shows that things placed in balance which are struck beyond their centre of gravity, force down the opposite parts placed on this side of the centre before mentioned. For example, let the quantity [surface] of the bird be *d e f* [Fig. 19] and its centre of revolution be *e* and the wind which strikes it be *a b d e* and *b c e f*: I say that a greater volume of wind strikes in *e f* the tail of the bird beyond the centre of revolution, than in *d e* on this side of the said centre: and for this cause the said bird cannot be upset above all, while holding its wings to the wind by the edge.

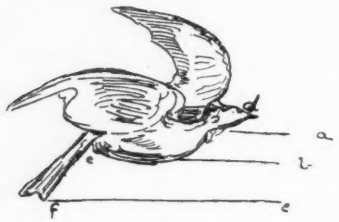


FIG. 19.

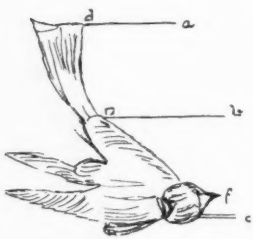


FIG. 20.

And if the bird is so that its length is under the wind it is liable to be turned upside down by the wind if it does not immediately raise its tail up. One proves it thus:—Let the length of the bird be *d n f* [Fig. 20], *n* is the centre of its revolution: I say that *d n* is struck by a greater amount of wind than *n f*; and for this reason *d n* will respond to the course of the wind, giving place to it, and moving downwards, thus raising the bird to the position of equality.

That the wing does not utilise all the pressure of the air and that this is true, note that the interstices of the primary feathers are spaces much wider than the width of the feathers themselves: therefore you who study flying should not calculate on the entire surface of the wing, and note the different varieties of wings for all flying creatures.

[Fol. 10 [9] *r.*]

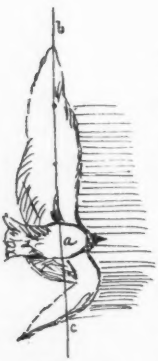


FIG. 21.

When the wind strikes the bird under its course from its centre of gravity towards this wind, then such a bird will turn itself with its spine to the wind, and if the wind were more powerful below than above then the bird would turn upside down, *if it did not immediately take care to draw in the under wing and stretch out the over wing; in this manner it rights itself and returns to the position of equilibrium.*

One proves it thus:—Let *a c* [Fig. 21] be the wing withdrawn under the bird, and *a b* be the extended wing. I say that the forces of the wind that strike the 2 wings will have the same proportion (ratio) as that of their extensions, that is to say *a b* to *a c*. It is true that *c* is wider than *b*; but it is so near the centre of gravity of the bird that it offers little resistance in comparison with *b*.

FIG. 22.

But when the bird is struck under the wind beneath one of its wings, then it would be possible for the wind to upset it, unless, immediately after it had turned with its breast to the wind, it stretched the opposite wing towards the earth, and shortened the wing which had been first struck by the wind, which wing remains superior and thus it will restore itself to equilibrium. One proves it by the 4th of the 3rd that is to say, *that object is the more affected which is attacked by the greater force;* again by the 5th of the 3rd that is to say *this support resists less and is situated farther from its fixed point;* again by the 4th of the 3rd *between winds of equal force [velocity] that will have the greater force [power] which has the greater volume* and that one will strike with a greater volume which finds a greater object; so that *m f* being longer than *m n* *m f* will obey the wind. [Fig. 22.]

[Fol. 10 [9] *v.*]

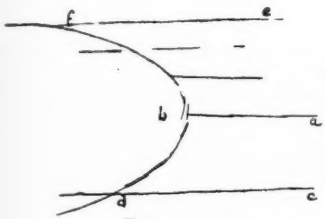


FIG. 23.

Struck from above, (up) the force of the wind which strikes it from above, has not full play, seeing that the wedge of wind, which is separated from the middle of the shoulder downwards [beneath], lifts the wing up with almost as much force as that exerted by the upper wind to depress the wing. One proves it: let *f b d* (and *b a b e*) [Fig. 23] be the shoulder of the wing: and *e f c d* (and) the sum total of the wind which strikes this shoulder of the wing, of which wind half is *a b c d* which strikes from the summit of the shoulder *b* down to *d*: and because the line *b d* of this shoulder is oblique, the wind *a b c d* forms a wedge at the contact *b d* and raises the shoulder: and the upper wind *a b e f* which strikes the obliquity *b f* makes a wedge there and pushes the wing down, with the result that these 2 said contraries prevent the shoulder from immediately entering beneath or above the arrival [course] of the bird, according to whichever its necessity requires: whence this necessity is met by putting a shaft on the round shoulder which acts as a buckler and immediately cuts the wind in such manner as the necessity of the bird demands as one shows in *m n* [Fig. 24].

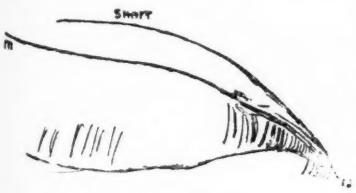


FIG. 24.

But if the wind strike the bird on the right or left wing, then it must enter below or above such a wind with the point of the wing that is struck by the wind [Fig. 25], which change occupies as much space as is taken up by the points of the wings: which change being under the wind, the bird turns with its beak to the wind and if it is on the wind, the bird

FIG. 25.

will turn with the tail at will: and here arises the peril that the bird will turn upside down, if nature had not provided for it by placing the weight of the body of the bird lower than the place of extension of the wings as one will show here.

[Fol. 12 [11] *r*.]

And lying is in such ill repute, that if it is said very great things concerning God it would (detract from the grace of the) Deity; and truth is of such excellence that if it praised trifles it would make them noble.

Without doubt, there is a similar proportion of truth to untruth as there is of light to darkness and this truth is in itself of such excellence that even if it be spread over humble and base matters, it exceeds beyond comparison the incertitudes and lies spread over great and very high discourses; because that still though our spirit may have lying for its fifth element, nevertheless the truth of things remains as the supreme nutriment for fine intelligences; but not for wandering humours.

But you who live by visions the sophistries and rogueries of boasters (please you more) in great and uncertain things please you more than those certain, natural and not of such great height.

The incident movements with their reflex movements are of 4 kinds, of which one, incident and reflex, is rectilinear, having lines of equal obliquity; the other is again rectilinear but the obliquities are different; the 3rd has the incident movement rectilinear and the reflex curvilinear; the 4th has the incident movement curvilinear and the reflex a straight line. Of these straights and curvilinears each of them is divided into 2 parts, because the first may have its incident movement rectilinear directly opposite to the chord of the arc made by the curvilinear reflex movement, and again this reflex may bend to the right or to the left of the incident rectilinear movement.

When the bird flies by beating its wings it does not fully extend its wings, because the points of the wings would be too distant from the lever and the nerves [sinews] which move it.

If in (lowering) the descent of the bird it rows backward with its wings, the bird will move rapidly; and this happens because the wings strike in the air which successively flows behind the bird, to fill the void that it has left.

[Fol. 12 [11] *v*.]

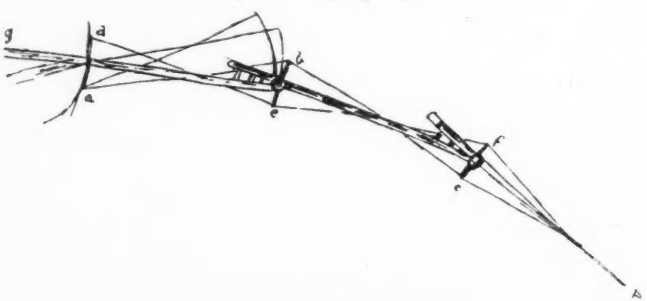


FIG. 26.

When *g* (*i*) descends *p* rises. [Fig. 26.]

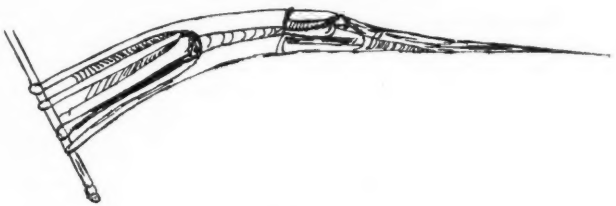


FIG. 27.

[Outline of a leaf here.]

[Fol. 13 [12] *r*.]

[Continuation of Fol. 9 *v*.] such a movement will bend and make it a semi-circle; then such a bird will be at the end of this movement with its beak turned towards whence such a reflexion began: which, if it be made against the arrival of the wind the end of the reflex movement would be made much higher than was the commencement of the incident movement, and this is the manner in which the bird rises, without beating its wings and in circulating; and the remainder of the said circumference would finish (with) by the sense of the wind, by incident movement always with one of the wings low, and similarly one side of the tail; and it then makes a reflex movement towards the flight of the wind and remains at the end with the beak turned to the flight of this wind and then makes incident and reflex over again, against the wind always circulating.

When the bird wishes to turn itself suddenly on one of its sides, then it quickly pushes the point of the wing on this side towards its tail, and because *all movement tends to its maintenance* or rather, *all moved bodies continue to move as long as the impression of the force of their motors remains in them,* the movement then of such a wing thrust with violence towards the tail reserving still at the end a part of the said impression, not being able by itself to follow the movement commenced at first, will move all the bird with itself, until the impetus of the moved air may be consumed.

The tail pushes with its face, and the wind struck by it, makes the bird move suddenly in the contrary direction.

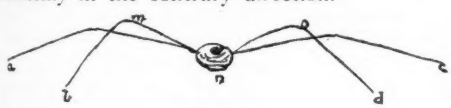


FIG 28.

When the bird shall be in the position *a n c* [Fig. 28] and shall wish to rise, it will elevate the shoulders *m o* and will thus be in the position *b m n o d* and the air will be pressed between the sides and the point of the wings, so that it will be condensed and cause an upward movement, and give rise to an impetus in the air, which impetus of the air will push the bird upwards by its condensation.

[Fol. 13 [12] *v*.]

To escape the peril of ruin.

The ruin of such instruments [machines] may happen in two ways, of which the first is that the instrument break; the second is that the instrument turn on its edge, or near its edge because it ought always to descend by a great obliquity or almost by the line of equality. . . . As to the protection of the instrument from rupture, one avoids it by making it of the greatest strength by no matter what line it may be able to turn itself, that is to say: either by the edge (or sense about the) falling either with the head or the tail first, or even with the point

of the right or left wing, or by the halves or quarters of the said lines as the design shows. As to turning by any side whatever of the edge, one ought to prevent it even in the beginning by making the instrument in such a fashion that in descending, under whatever aspect that may come about the prevention should be ready; and this will be done in giving its centre of gravity on the centre of the weight carried by it, always in a straight line, and one of the centres very distant from the other; that is to say, that in an instrument 30 fathoms wide these centres may be 4 fathoms apart, and that one, as mentioned, be situated under the other and the heavier underneath, so that in the descent, the heavier portion might always be the guiding portion of the movement. Further than that, if the bird should fall head first (1) with such obliquity as would turn it upside down, the latter would not be able to happen, because the lighter portion would be under the heavier, a thing which is impossible in a long descent as one proved in the 4th of the mechanical elements.

And if the bird fall with the head underneath (with the body) with part obliquity of the body turned to the earth, then the sides of the wings underneath ought to turn flat against the earth and the tail be raised towards the loins (back), and that the head and the underneath of the jaws be turned also towards the earth, whence its reflex movement will commence immediately in such a bird, which will cast it back towards the sky; on this account such a bird will, at the end of this reflexion begin to fall backwards, unless in its rise, it lowers one of its wings a little, which

[Continued on Fol. 12 recto.]

[Fol. 14 [13] *r.*]

Here, the big fingers of the wings are those which hold the bird still in the air against the movement of the wind: that is to say, the wind moves on which it supports itself without beating its wings and the bird does not change its place. The reason of this is that the bird arranges its wings on such an obliquity that the wind, which strikes it underneath does not cause a wedge of such a nature as would lift it up, but lifts it up however just as much as its weight would press it down, that is to say: if the bird fall with a force of 2 the wind would lift it up with another force of 2 and because equal things do not surpass one another, this bird remains in its place without rising or falling. It remains for us to speak of movement which drives it neither forward nor backward: and this happens if the wind accompanies it or rather pushes it out of its place with a force of 4, and the bird with the same force inclining with the said obliquity against the wind: here also the powers being equal such a bird will not move forward nor be driven back, the wind being equal. But because the movement and powers of the winds are variable, and the obliquities of the wings ought not to be changed, for if the wind should increase, and it overcame the obliquity, in order not to be pushed upwards by this wind. . . .

[In Margin.]
One will carry snow in summer, taken from the high crests of the mountains and one will let it fall in places of festival in the summer time.

The wind does not enter, in the above mentioned cases, as a wedge under the obliques wings, but reaches the wing only at the edge which tries to descend against the wind, whence it strikes the edge of the shoulder, which shoulder acts as a buckler for the rest of the wing: and here the descent of the wings would not have any defence if the great finger *a* [Fig. 29] were not there which then faces front, and itself receives all the force of the wind directly on it or less than directly, according to the more or less great force of the wind.

FIG. 29.

[Fol. 14 [13] *v.*]

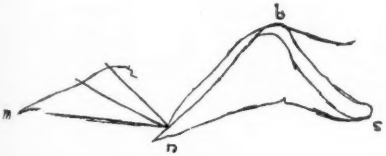


FIG. 30.

The big (thumb) finger *n* [Fig. 30] of the hand *m n* is that which, when the hand is lowered, is lowered more than the hand, so that it closes and prevents the escape of the air pressed by the descent of the hand, so that in this place the air is condensed and resists the oars of the wings and therefore nature has provided such a finger with a bone of great strength, to which strong nerves [sinews] and short feathers are joined. The short feathers have greater strength than the other feathers of the wings of birds will have, because that by them the bird supports itself on the air already condensed with all the force of the wing and of its strength, because it is that by which the bird is moved forward: and this finger does the same work for the wings that the claws do for the cat when it climbs on the trees.

But when the wing recovers a new force with its return upwards and forwards, then the big finger of the wing puts itself in a straight line with the other fingers, and thus with its cutting extremity divides the air and does the work of a shaft which always cuts the air by some movement, high or low, that the bird would rise.

The second shaft in the opposite portion, beyond the centre of gravity of the bird, and that is the tail which, if it is struck by the wind underneath, since it is beyond the said centre, it will cause the forward portion of the bird to lower. And if this tail be struck on top the forward portion of the bird will rise. And if this tail twist a little, and turn its under surface obliquely to the right wing, the anterior portion of the bird is turned to the right side. And if it turn this side obliquity of the under surface of the tail to the left wing, it (the bird) will be turned with its forward portion toward the left side: and in each of the two manners the bird will sink. . . . 4

[In Margin.]

4. But if the tail, placed obliquely, be struck by the wind on its upper surface, the bird (it) will be turned, in turning the tail slowly from this side where the superior surface of the tail shows its obliquity.

-vity

[Fol. 15 [14] *r.*]

The pivot of the shoulders of birds is that which is turned by the muscles of the chest and of the backbone; and it is there that the discretion arises of lowering or raising the elbow according to the will or necessity of the animal which is moving.

I conclude that the mounting of the bird without the beating of wings, is caused by nothing other than its circular movement which, when it starts from the arrival of the wind sinks until it reaches the place where the reflex movement begins after which and so circulating, it has described a semi-circle and its face turned to the wind, and follows the reflex movement, on the wind still circulating until, with the help of the wind it makes its greatest height between its lowest and the arrival of the wind and is left with the left wing to the wind; and from this greatest height again circulating, it descends to the last incident movement being left with the right wing to the wind. As if to say:— The wind goes from *a* to *c* [Fig. 31] and the bird moves from *a* and sinks from *a b c* and in *c* it makes the reflex movement

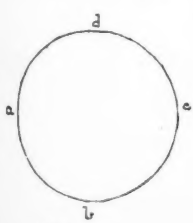


FIG. 31.

as in *c d a*, and by the favour [help] of the wind it is much higher at the end of the reflex movement, which end of the reflex movement is started perpendicularly over the said commencement of the incident movement.

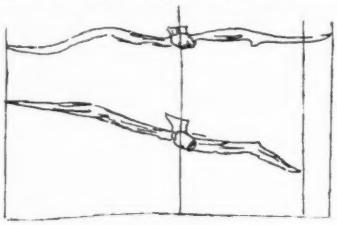


FIG. 32.

The equal resistance of the bird's wings always springs from the fact that they [the wings] are equally distant, at their extremities, from the centre of gravity of any bird. [Fig. 32.]

But when one of the extremities of the wings is nearer the centre of gravity than the other extremity, then the bird will descend from that side where the extremity of the wing is nearer the centre of gravity.

[The last syllable *—vity* is found on Fol. 14 [13] *v.*]

[Fol. 15 [14] *v.*]

The hand of the wing is that which gives the impetus; and then the elbow is turned with the edge forward so as not to hinder the movement which created the impetus; and when this impetus is afterwards created, the elbow is lowered and made oblique and being oblique it makes the air on which it lies as in the form of a wedge on which the wing raises itself, and if the movement of the bird were not so performed, during the time that the wing moves forward the bird would sink towards the end of the impetus; but it is not able to sink because as much as the impetus lacks so much the percussion of the elbow resists this descent and lifts up the bird.

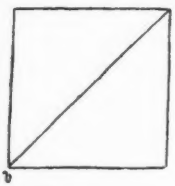


FIG. 33.

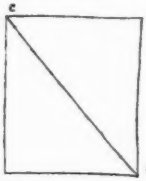


FIG. 34.

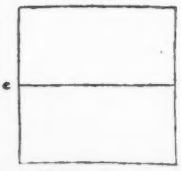


FIG. 35.

Let us say, that the impetus be as 6 and that the bird weigh 6 and that in the middle of the movement the impetus become 3 and that the weight still remain 6; here the bird would sink by half-movement, that is to say, by the diameter of the square, and the wing oblique with the contrary aspect, also by the diameter of this square does not allow such a weight to sink, neither does the weight permit the bird to rise; consequently it moves in a straight line. That is to say: the descent of the bird during the said half-movement would be by the line *a b* [Fig. 33] and, because of the obliquity of the wings with contrary aspect would have to rise by the line *d c* [Fig. 34]; whence, from the above-mentioned causes, it moves on the place of equality *e f*. [Fig. 35.]

The elbows of the animal are not lowered just at the commencement because in the principal flight of the impetus the bird would jump upwards, but they are lowered just so much as is necessary to prevent the descent according to the will and discretion of the bird.

When the bird wishes to glide suddenly upwards it lowers the elbows immediately after it has created the impetus.

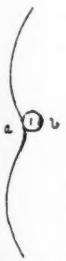
But if it wishes to descend, it holds the elbows up firmly after the creation of the impetus.

[Fol. 16 [15] *r.*]

You are to remember that your bird ought not to imitate anything but the bat, because the membranes [web] form an armour or liaison to the armour, that is to say, mistress of the wings.

And if you imitate the wings of the feathered birds, the wings are more powerful in bone and nerve, through being pervious: that is to say, the feathers are disunited permeable to the air. But the bat is aided by the membrane which binds the whole and is not pervious.

Of the method of balancing oneself.



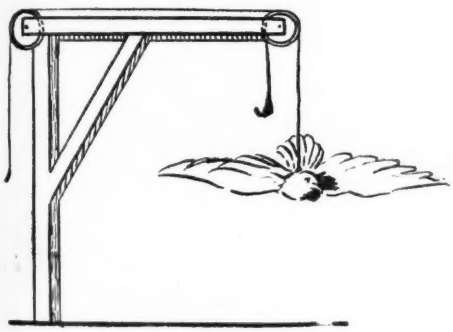
It is always the heaviest portion of the body which guides its movement.

Then the bird finding itself in the position *a b* [Fig. 36], *a* being lighter than *b*, where the motive power is disposed it will always keep above *b*, so that it will never happen that *a* will precede *b* except by accident, which will not last long.

The bird which has to rise without beating its wings, places itself obliquely against the wind, presenting the wings to the latter with its elbows in front, with the centre of its gravity more towards the wind than the centre of the wings, whence it happens that if the obliquity of the bird would sink with a force of 2 and that the wind strikes it with a force of 3, this movement obeys the 3 and not the 2.

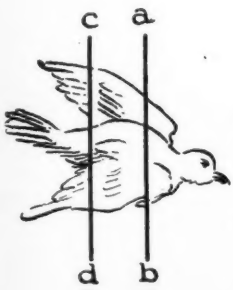
FIG 36.

[Fol. 16 [15] *v.*]



This [Fig. 37] is done to find the centre of gravity of the bird, without which instrument, this instrument would have little value.

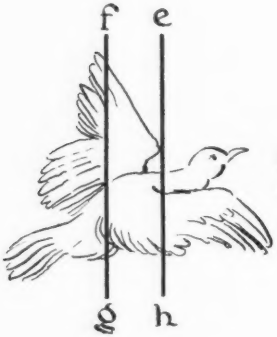
FIG. 37.



When the bird sinks, then the centre of gravity of the bird is outside the centre of its resistance; as if the centre of gravity were on the line *a b* and the centre of resistance on the line *c d* [Fig 38].

And if the bird wishes to rise, then the centre of its gravity remains behind the centre of its resistance.

FIG. 38.



As if the centre of gravity mentioned might be in *f g*, the centre of resistance would be in *e h*. [Fig. 39.]

FIG. 39.

The bird is able to rest in the air without holding its wings in the place of equality because not having its centre of gravity at the middle of the pivot, as balances have, it is not constrained by necessity to hold its wings at an equal height, as in the said balances. But if the wings are outside this place of equality then the bird will descend by the line of obliquity of these wings; and if the obliquity is compound, that is to say, double, as for example, that the wings decline to the south, and that the obliquity of the head and tail declines to the east, then the bird will descend with the obliquity to the south-east. And if the obliquity of the bird be double that of the wings then the bird will descend in the middle between the south-east and the east, and the obliquity of its movement will be between the two said obliquities.

[Fol. 17 [16] *r.*]

Persuasion in haste (or persuasion of the enterprise) *which removes the objections.*

If you say that the nerves and muscles of the bird are, beyond comparison, of greater power than those of man seeing that all the flesh of so many muscles and pulps of the breast is made for the benefit and augmentation of the movement of the wings, with this bone of the breast all in one piece which provides the bird with great power, with the wings a tissue of great nerves and other very strong ligaments of cartilage and a skin made very strong with diverse muscles: here one replies that so great a force is provided for power because that beyond just sustaining itself by its wings it must at will double and triple the movement in order to escape pursuit or to follow its prey, whence, in such an effect it is necessary for it to double or triple its force, and

Wine-skins, where a man, falling from a height of 6 fathoms, would not injure himself, falling either in water or on land: and that these wine-skins, fastened together in the fashion of beads, are surrounded by others.

Man, also, has a greater amount of strength in his legs, than is necessary for his weight: and that this is true, place a man upright on some mud and note how deeply his foot sinks. Then place another man on his back and you will see how much deeper he sinks. Then, having removed the man from his back, make

beyond that, carry as much weight in its claws, in the air, as equals its own weight: as one sees the falcon carry the duck, and the eagle the hare, by which thing it is very well demonstrated where such super-abundant force is distributed: but it needs little force to sustain itself and to balance them on the currents of wind and to direct the shaft in its paths: a little movement of the wings is sufficient and as much more slow movement as the bird is larger.

him leap straight up in the air, as far as he can, and you will find the imprint of the foot deeper from the leap, than with the man on his back: therefore it is here proved in two manners, that a man has more than double the force that is requisite to sustain himself.

[Fol. 17 [16] *v.*]

If you fall, see that you strike the ground with the double wine-skin that you hold under you.

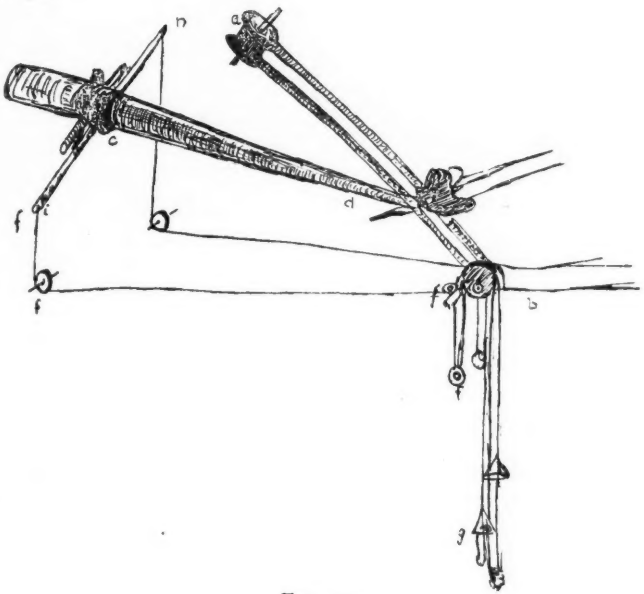


FIG. 40.

Because the wings have to row below and behind in order to keep the instrument up, and that it may move forward, the movement of the lever *c d* [Fig. 40] is made by an oblique way, guided by the strap *a b*.

I could make it so that the foot which presses the stirrup *g* might be that which beyond its ordinary function should draw down the lever *p*. But this would not be according to our design because we require that the lever *f* may rise or sink before the stirrup *g* move from its place, in order that the wing in throwing itself forward, or lifting itself up (during the time in which the impetus, already acquired is moving the bird forward, without the beating of the wings) may be able to put the wings in the air by the edge, because if that were not done, the face of the wings would strike the air, hinder the movement, and prevent the impetus from carrying the bird forward.

[Fol. 18 (recto).]

Always in the elevation of the hand, the elbow is lowered and presses the air, and in the lowering of this hand the elbow is raised and remains by the edge lest it hinder the movement by means of the air that strikes therein.

The lowering of the elbow at the time when the bird moves the wings forward by the edge a little on the wind guided by the impetus already acquired causes the wind to strike under this elbow and form a wedge on which the bird with the said impetus, without beating its wings, mounts up and if the bird is 3lbs. and the breast 1/3 the width of the wings, the wing will feel but 2/3 of the weight of such a bird.

The hand feels a great fatigue towards the big finger, or rather shaft of the wing, because it is this part which strikes the air.

The palm of the hand goes from *a* to *b* always between angles almost equal declining and pressing the air, and at *b* turns immediately by the edge and goes behind rising by the line *c d*, arrived at *d* it is turned suddenly in front and goes sinking by the line *a b* and in turning does so always around the centre of its width. [Fig. 41.]

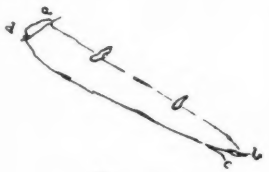


FIG. 41.

The recoil of the hand, by the edge will be made with great speed and the pressure behind, in front, will be made with that speed which the last power of the motor requires.

The course of the point of the fingers is not the same going as returning but the return is through a higher line: and under this is the figure made by the superior and inferior line, and oval with a long and narrow curve.

[Fol. 18 (verso).]

1505 Tuesday evening on the 14th of April Laurent came to live with me, he says he is 17 years old. And on the 15th of the said April I had 15 florins of gold from the chamberlain of San Maria Nova.

From the mountain, which bears the name of the great bird, the famous bird will take its flight, and will fill the world with its great fame.

To raise a tree by *p* and *r s* sustain [Fig. 42].

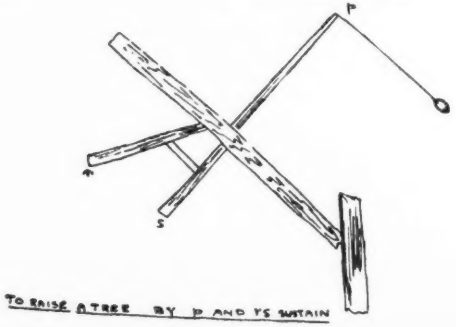


FIG. 42.

[Back Cover—Inside.]

lad,	48	
husks	44	
in straw	23	
key	.6	148
myself	28	111
chicken	.2	—
	—	037
	111 (8)	
	(11)	
	.28	
	—	
	83	

The great bird will take its first flight, on the back of its great swan, and filling the universe with stupor, filling all writings with its renown, and glory eternal to the nest where it was born.

REVIEW OF AIRSCREW THEORIES

BY A. R. LOW.

The following letter from Dr. Enrico Pistolesi, the well-known Italian aeronautical engineer, continues the discussion :—

Dear Sir,

I have read in No. 196, February, 1923, of the Journal of the Royal Aeronautical Society, the interesting communication read by you and the important discussion following.

While expressing the pleasure of a modest worker like myself in the captivating argument, I permit myself to send some of my publications, from which you will see that the ideas so lucidly expressed by yourself were expounded by me in a paper in January, 1921, to the Ass. Ital. di Aerotechnica, and since developed at length in succeeding papers.

The latest is actually in press, and it will be my care to send it to you as soon as published.

These reproduce substantially my "Course for Aeronautical Constructors" at the Royal Polytechnic of Turin. They have some analogy with Mr. Glauert's work, but were (in their formulation, if not always in date of publication) prior to it and entirely independent of it. Further, they show a much more advanced stage of working out, and are capable of immediate application in practice.

Believe me, etc.,

ING.-DOTT. E. PISTOLESI.

Enclosed :—

(1) La Teoria dei Vortici in Aerodinamica, 25th January, 1921.
(2) Nuovi Indirizzi e Sviluppi della Teoria delle Eliche, January, 1922.
(3) I Propulsori Elicoidali e i Recenti Progressi dell'Aerodinamica, 15th October, 1922.

Commenting on the above, in (1) Dr. Pistolesi gives a brief statement of the Kutta-Joukowski transformation, and of the Lanchester-Prandtl trailing vortex system, and of the Karman stable system of transverse vortices. He then considers Prandtl's application of the theory to the limiting case of an airscrew with a very large number of small blades, and obtains the inflow correction of $v/2$ and $w/2$, applied to the coefficients for infinite aspect ratio. He remarks that although the rotary inflow effect may be physically eliminated by the interference of the equal and opposite circulation round the blade, yet it must be taken into account in correcting the results obtained on the simple Drzewiecki theory. It will be seen that his position is so far identical with Mr. Glauert's, and, of course, in agreement with Prandtl's original result.

In (2) and (3) Dr. Pistolesi develops a very complete discussion of airscrew theories covering substantially the same ground as the writer's "Review." The treatment is strictly mathematical, and the learned author shows a satisfying mastery of the technique of the various methods.

Reference is made to the work of Froude, Rankine, Drzewiecki, Soreau, to the development of the "inflow" corrections by Fage, Riach, de Bothezat, to the work of Durand and Warner, and to the application of the cascade method by McKinnon Wood. Finally, the author examines these methods in the light of

the Lanchester-Prandtl vortex theory, particularly with regard to Betz's paper "Screw Propellers with Minimum Energy Losses" (Göttingen, 1919).

One point is left outstanding—the validity of applying the results of the limiting case with a very large number of blades to a screw with two, three or four blades. On page 217 of (3) he quotes Betz's integrals for the velocity components due to a spiral vortex trailing from the blade tip, found in a slightly different form by the present writer.

The evaluation of these integrals will finally decide the true inflow correction for a screw with a small number of blades.

A. R. Low.

CORRESPONDENCE

To the Editor of the JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY.

Paris, le 28 février, 1923.

MESSIEURS,—Nous avons noté, dans votre numéro de février, 1923, que M. le Major A. R. Low, membre de votre Société, se réfère, dans son étude générale sur la théorie de l'hélice, à une étude de M. Margoulis qui aurait été publiée en supplément par "L'Aerophile." Vous voudrez bien noter que c'est "L'Aeronautique" qui a publié ce travail en supplément à son numéro de mars. Nous avons d'ailleurs eu le plaisir d'en adresser un exemplaire à Mr. A. R. Low.

Veuillez agréer, Messieurs, l'assurance de nos sentiments distingués.

H. BOUCHÉ.

REVIEWS

Mechanical Testing (Vol. II.)

Batson and Hyde. (Chapman & Hall.)

In this book the authors have collected a large amount of information which is not to be found in any other single volume. As a treatise on the methods of testing prime movers, machines, structures, etc., it is rendered more complete by the inclusion of descriptions of many commercial forms of apparatus, and the unique opportunities enjoyed by the authors for examining and using such apparatus in the course of their work in the Engineering Department of the National Physical Laboratory has enabled them to give practical working hints and advice of a type which is frequently missing from the instruction sheets of the manufacturers.

Although the volume deals with mechanical tests in general (or perhaps more correctly with those mechanical tests which have been referred to the N.P.L.), there are few sections which do not affect some aspect of aeronautical work. The first nine chapters, dealing with various forms of dynamometer and apparatus for the measurement of power, torque, thrust, gear efficiency, etc., are of direct interest to engine users and testers. So also are the chapters on the testing of balance (static and dynamic), lubrication and bearings.

The effect of vibration on aeroplane structures is attracting much attention at present, and the chapter on vibration tests contains a considerable amount of pertinent matter. The vibration tests of streamline wires (described on page 187) do not produce the type of failure which is most commonly found in service. As has recently been demonstrated, the combined effect of torsional and bending movements, generated and sustained under certain conditions of air flow, probably cause the typical diagonal fractures which occur near the end of the flattened portion of the wire.

Extended experience in the devising of suitable forms of test for lock nuts indicates that simple methods of the type suggested on page 189 give misleading and anomalous results. It is no uncommon experience in such tests to find that two ordinary nuts locked together give apparently better results than can be obtained with certain well-known forms of lock nut which have been used in thousands on railways, etc., with satisfactory results.

The chapter dealing with columns and struts, although including experimental work on spruce struts and on steel tubular struts (closed and split), contains no reference to the important work of Southwell, Robertson or Wylie, and is therefore incomplete from the aeronautical standpoint.

Two chapters are devoted to descriptions of wind channel and hydraulic apparatus.

The use of springs for instrument and test apparatus generally is discussed in Chapter X., and many useful tips are given. Table III., which gives the relative energy-storing capacity of various types of spring, might have included helical springs of hollow material, which are more efficient on a weight basis than those made from solid material.

Reference is made to tension meters, and two types are briefly described.

No form of accelerometer is included though the measurement of acceleration forces is within the scope of the book.

The remaining portions of the book, although apparently extraneous to aeronautical practice, will repay examination, as the design principles of much of the apparatus and the methods of many of the tests are capable of wider application.

WM. D. D.

which
ods of
ete by
nd the
such
of the
hints
eets of

erhaps
to the
autical
er and
, etc.,
ers on

tention
unt of
ge 187)
e. As
ending
flow,
of the

k nuts
eading
nd that
can be
used in

experi-
), con-
ie, and

draulic

scussed
es the
ncluded
is than

bed.
ccelera-

o aero-
of the
ication.
D. D.